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A FUNCTIONAL DESIGN OF AN INGRESS-EGRESS SYSTEM FOR AN OCEAN BOTTOM STATION (U)

1 October 1968

Final Report
Prepared for
U.S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California
Under Contract N62399-68-C-0020

Report No. CR 69.003

by

WESTINGHOUSE ELECTRIC CORP.
OCEAN RESEARCH & ENGINEERING CENTER
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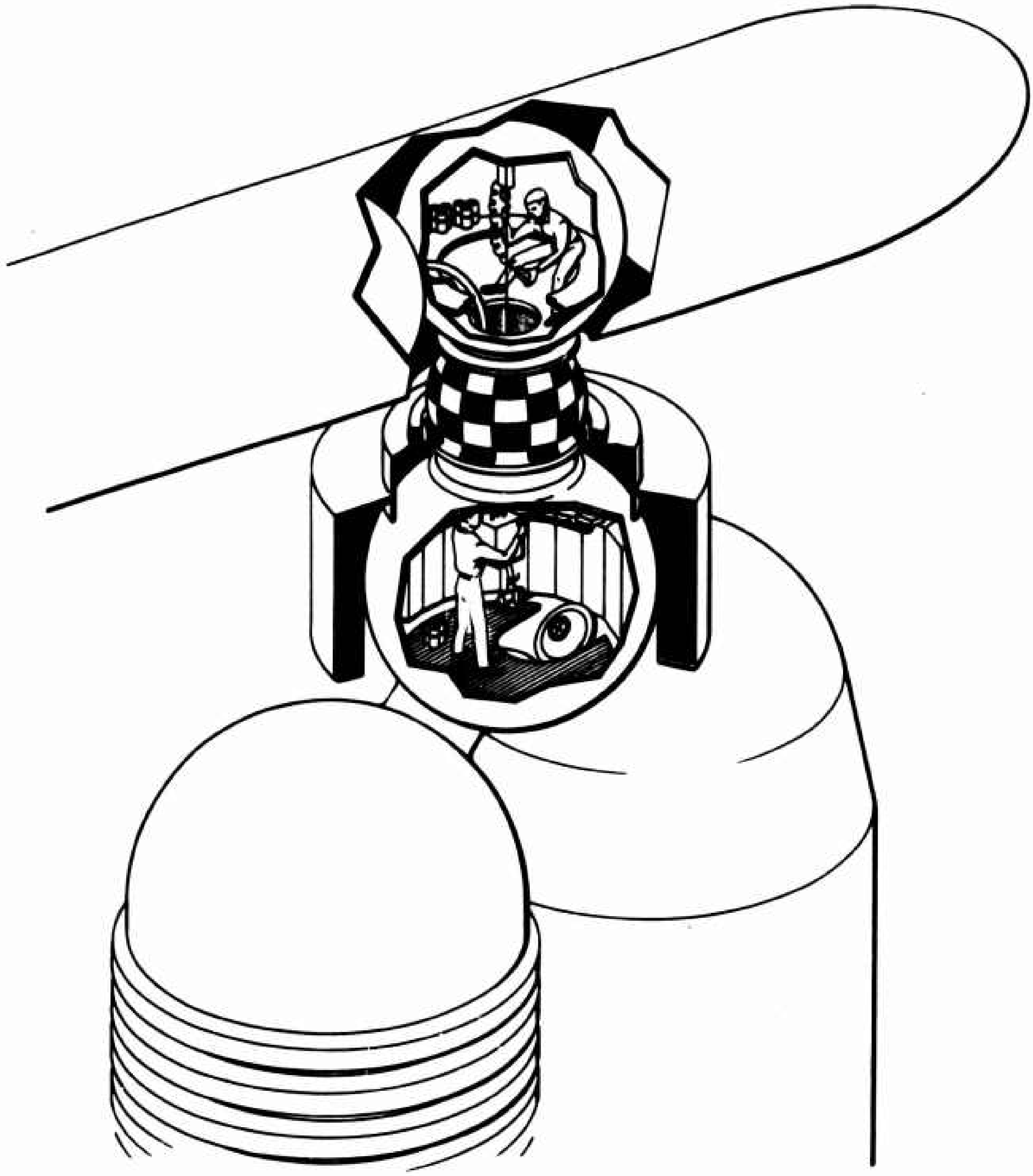

Frontispiece -- IES During Station Resupply

PREFACE

The purpose of this report is to provide a functional design for an Ingress-Egress System for a Manned Underwater Station. The Station, being developed under the cognizance of the U. S. Naval Civil Engineering Laboratory is a first generation prototype which will serve as an engineering test station for further development of manned deep ocean construction concepts.

The referenced manned underwater station concept has been developed by the Electric Boat Division of the General Dynamics Corporation in a report under contract No. 62399-67-C-0044. The Ingress-Egress System has been designed within the framework of this concept.

The work reflected in this functional design was performed under contract No. N62399-68-C-0020 by the Westinghouse Ocean Research and Engineering Center, Annapolis, Maryland.

SUMMARY

The Ingress-Egress System provides means to supply a Manned Underwater Station with a replacement crew and fresh consumables.

The baseline system incorporates a Deep Submergence Rescue Vehicle as a resupply submersible and an ASR-21 as a surface support ship. Access to the Station is attained through a nine-foot diameter sphere located at the top of the Station structure.

This report presents the results of the design effort, the constraints and rationale which influence design decisions and alternative solutions to design problems. Drawings, outline specifications and recommendations for future work are included.

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1.0 SYSTEM CONSTRAINTS

The Ingress-Egress System (IES) described in this report is constrained by three major factors: the configuration of the concept Station (as defined by General Dynamics), the environment to which the Station is subjected and the logistic requirements of the Station. As shown in Figure 1-1 these three factors overlap to prescribe the boundaries within which the IES must be designed. In order to provide a truly functional system these overlapping areas must be defined.

1.1 STATION CONFIGURATION

The Station is a structure approximately 50 feet high utilizing two vertical cylinders; one for habitation and one to contain a reactor or other power source (see Figure 1-2). The two cylinders are encircled by ballast tanks. An observation sphere equipped with view ports and lights is attached below the habitat cylinder. Attached to the observation sphere are two smaller spheres which provide lockin-lockout capability for material retrieved by the manipulator which is also attached to the observation sphere.

Atop and between the habitat and reactor cylinders is a spherical access chamber surrounded by a flotation holding tank. A platform surface for mating with the replenishment vehicle is installed above the holding tank.

The Station, when emplaced on the sea floor, is ballasted to approximately neutral buoyancy and stabilized by four legs and a cable attached to a clump anchor. Station ascent and descent is normally controlled by the anchor cable winch and ballast adjustments.

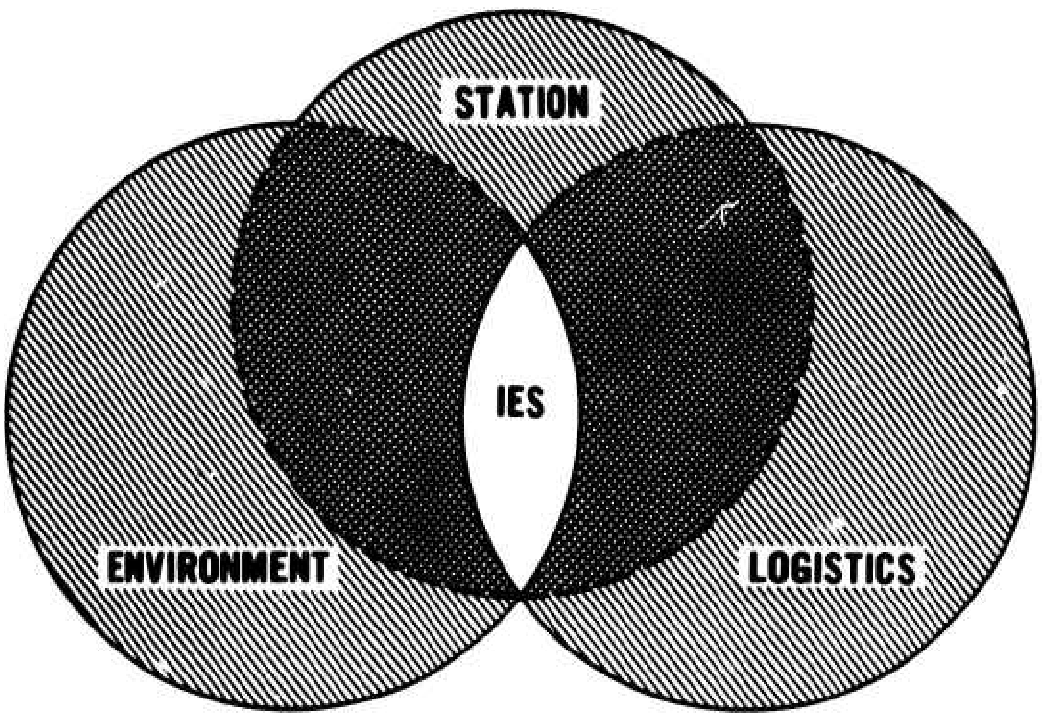

Figure 1-1.

System Constraints

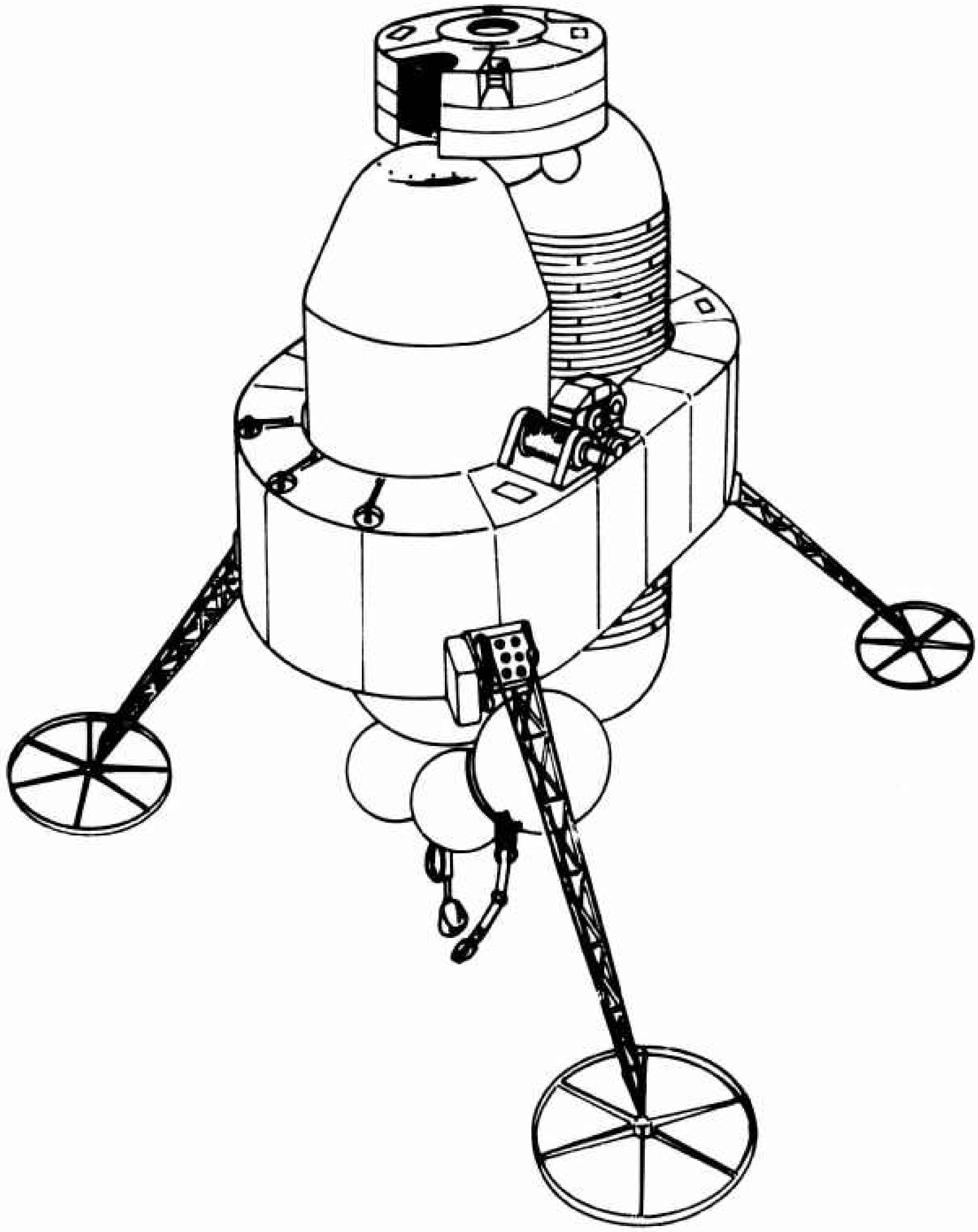

Figure 1-2.

Manned Underwater Station - Reference Concept

1.2 ENVIRONMENT

The design environment of the Ingress-Egress System encompasses the sea surface conditions in which support vessels must operate above the Station site, the water column through which resupply vehicles must descend, and the conditions at the bottom under which cargo and personnel must be transferred.

Environmental considerations fall into two main categories: those for which the IES must be designed to assure successful operation at a generalized site (i. e., on the ocean bottom at 6,000 feet) and those which vary with site location.

Factors which affect the design at a generalized bottom site are hydrostatic pressure, water temperature, currents, and fouling.

Factors which vary with site location, and in some cases with season and weather patterns, are sea state, surface currents, bottom visibility, fouling (at intermediate depths), temperature, salinity and density profiles, bottom topography, composition, and bearing strength and seismic activity.

1.2.1 Design Parameters

The IES environmental design parameters are listed in Table 1-1. These parameters are a composite of those compiled during investigations of three candidate Station sites (see Section 3) and should be considered as generalized parameters.

Review of data indicates that, excluding anomalies which exist in areas such as the Red Sea and the Mediterranean Sea, hydrostatic pressure and temperature at 6,000 feet is relatively invarient throughout the world, and falls within a very narrow band in the mid-Pacific. Current data at 6,000 feet is rare; however, by avoiding certain areas, such as those adjacent to submarine canyons which tend to experience turbidity currents, design problems can be minimized.

TABLE 1-1.

IES ENVIRONMENTAL PARAMETERS

PARAMETER	RANGE
Depth	0 - 6,000 feet
Ambient External Pressure	0 - 2,700 psig
Ambient External Temperature	2.0 - 30° C
Water Density	64.37 - 64.67 lbs/cu. ft.
Water Salinity	33.0 - 35.5 o/oo
Sea State	0-3 (Douglas Sea Code, see Figure 3-3)
Water Currents - Surface	0 - 3 knots
Water Currents - Bottom	0 - 2 knots
Visibility - Bottom	0 - 400 feet

Typical data for deep areas near San Clemente and the Hawaiian Islands are shown in Table 1-2. Note that there is little variation between the two areas even at a difference in depth of 1,200 feet. Note also that there is even less variation between various points at the same depth.

TABLE 1-2.

BOTTOM WATER DATA
HAWAIIAN ISLANDS/SAN CLEMENTE

Latitude N	Longitude W	Depth (feet)	Temperature °C	Salinity 0/00	Sigma-t
22° 53'	151° 15'	6336	2.33	34.60	27.65
22° 31'	153° 56'	6084	2.37	34.58	27.63
22° 01'	155° 49'	6468	2.30	34.62	27.66
22° 59.6'	157° 21.8'	6450	2.20	34.62	27.67
22° 16'	158° 34'	7004	2.15	34.58	27.65
23° 45'	150° 0'	6432	2.18	34.65	27.70
23° 13'	151° 56'	6264	2.09	34.60	27.67
32° 32.5'	118° 12.2'	4896	2.85	34.56	27.57
32° 23.9'	118° 11.8'	4884	2.90	34.56	27.62

1.2.2 Biological Fouling

To a large extent the problems of biological fouling are mitigated by the operational depths of the Station. Typical fouling organisms such as tunicates, bryozoa and barnacles, normally found on structures submerged in shallow water are not known to collect on metal submerged at depths of 3,000 feet and below. Due to the absence of light sufficient to support photosynthetic process, organisms which depend on these processes either directly or indirectly should not constitute a significant problem below the euphotic zone (surface to 300 feet).

At depths below 3,000 feet, slime and hydroids as well as carnivores and detritus feeders such as crabs, anemones, tube worms and gastropode have been found sparsely distributed on metal panels. These organisms are likely to inhabit the Station site and should be kept cleared from mating surfaces and mechanisms. Techniques to combat shallow and deep fouling are discussed in Section 2.2.

1.3 LOGISTICS

Resupply for the Station involves the delivery of a fresh crew and sufficient food and other consumables to extend mission capability for 30 days. Resupply will normally be accomplished with the Station on the ocean bottom. Table 1-3 summarizes resupply requirements.

1.3.1 Life Support Supplies

The life support subsystems are designed to provide a one atmosphere environment by supplying oxygen, removing carbon dioxide and controlling the temperature and humidity in the Station. The recommended atmosphere management system includes self-contained chlorate candles for oxygen supply and lithium hydroxide for carbon dioxide removal. In addition, the air is cooled, dehumidified, and deodorized to provide a comfortable environment.

TABLE 1-3.

RESUPPLY REQUIREMENTS (5 Men - 30 Day Mission)

RESUPPLY	WEIGHT (lb.)	VOLUME (ft^3)	REMARKS
1. Manning & Effects	1,225	75	5 men x 245 lb; (includes allowance for recreational material, such as films, books, tapes, etc.)
2. Food	675	28	Avg. density 24.5 lb/ft^3
3. Water	1,920	31	(230 gallon)
4. Oxygen Generation	890	12	45 Chlorate candles (container size - 12 in. x 6-1/2 in. dia.)
5. CO_2 Removal	660	21	82 Lithium hydroxide canisters (canister size 12 in. x 6-3/4 in. dia.)
6. Charcoal Filtration	80	5	8 bags 10 lb. each
7. Miscellaneous	50	2	Fiberglass filter, medical supplies, damaged tools, etc.
	5,500	174	

REMOVAL	WEIGHT (lb.)	VOLUME (ft^3)	REMARKS
1. Manning & Effects	1,225	75	See above
2. Liquid Sanitary Waste	2,530	41	(305 gallon)
3. Bulk Waste	1,745	58	Expended canisters, refuse, charcoal, filter, etc.
	5,500	174	

The average oxygen consumption per man in the habitat will range between 0.9 - 1.0 standard cubic feet per hour. This indicates a requirement for a 3,600 standard cubic foot (scf) supply for a 30 day mission cycle. A five day emergency supply is included as part of the initial Station provisioning. The recommended chlorate candle contains sodium chlorate, iron, barium peroxide, glass wool filter and a bouchon and generates 90 scf of oxygen and 8,300 btu in a period of 50 minutes. Each chlorate candle is 12 in. high by 6-3/4 in. in diameter and weights 20 lbs. Allowing for a 10% margin of safety, 45 candles are required to satisfy oxygen needs for 30 days.

Carbon dioxide is produced normally by man at the rate of 0.09 - to 0.1 lb. per hour. This requires the removal of 360 lbs. of CO_2 during the specified mission. Standard Navy lithium hydroxide canisters with an operational life of 50 man-hours per can are recommended. Each canister weighs 8.2 lbs. and is 6-3/4 in. dia. by 12 in. tall. To meet needs for a complete cycle with a 10% safety factor requires 82 lithium hydroxide canisters.

Additional items required to complete the atmosphere conditioning during the mission include unimpregnated activated coconut shell charcoal to control odors and remove organic vapors, and a high efficiency absolute filter to remove solid or liquid particulate matter. The specified filter is a Fiberglass type.

1.3.2 Food

The dietary requirements for the crew have been established at between 2,800 - 3,200 kilo calories per day. This is estimated on the basis of their anticipated physical activity and the environmental conditions. Caloric allowances can be varied somewhat by using foods rich in calories. Food supplies will be generally of the frozen variety (i.e., TV dinners, frozen fruit, frozen juices) primarily for ease in handling, palatability, and long storage life. Dry food supplies such as cereals, coffee,

tea, milk and snacks will round out the daily menu. This type of food supply has been chosen to reduce food volume and to minimize garbage and refuse production. The disposable food trays and utensils, for instance, will be wrapped in plastic bags and stored in the freezer to prevent bacterial growth. Precooked foods are used where possible to minimize the fuel required for cooking and preparation time.

The volume and weight of food required for the mission is a multiple of the mission man-day duration with 4.5 lbs. of food allotted per man-day yielding a total of 675 lbs. The food stores volume requirements have been established, based upon an assumed average density for both frozen and dry stores of 24.5 lb/cu. ft.

1.3.3 Water

For liquid requirements, 1920 lbs. of potable water are provided. Of this water, 6.5 lbs/man-day is allotted for drinking and beverage reconstitution and 6.3 lbs/man-day is provided for personal hygiene and toilet flushing. This is sufficient fresh water to take care of all the crew personal hygiene needs for the entire mission in the event that the Station condensate make-up water system fails to generate an adequate supply.

1.3.4 Sanitary Waste

During a 30 day period over 300 gallons of sanitary waste will be collected from the head and galley. This waste must be stored during the mission cycle and removed from the Station as part of the resupply operation, along with refuse and expended material containers.

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2.0 SYSTEM DESCRIPTION

The two major elements of the system are the resupply vehicle and the Station access chamber. The interface between the two, the docking and mating mechanism, is also a significant consideration. These elements and their interaction under the constraints described in Section 1 constitute the basic Ingress-Egress System. The resupply plan and outline specification described in Section 2.4 and 8.0 respectively further define the system.

2.1 RESUPPLY VEHICLE

The Deep Submergence Rescue Vehicle (DSRV) has been selected as the prime resupply vehicle. The first DSRV (Figure 2-1), now under construction, is scheduled to be operational in 1970. This vehicle will have a maximum depth capability of 3,000 to 3,500 feet and a payload capacity of approximately 4,800 lbs. Subsequent vehicles will operate to 6,000 foot depths, and could be modified to increase payload to 6,000 lbs (see Section 6.3). Selection of the DSRV was based on results of a survey of planned and operational submersibles (see Section 4).

2.1.1 Vehicle Description

The DSRV has been designed to navigate to and to mate with a submerged structure (a disabled fleet submarine), to transfer safely, in shirt sleeve environment, as many as 24 men at one time from structure to vehicle and return to the surface. The vehicle has a number of special features and capabilities which are to date unique. The pressure hull is constructed of three intersecting spheres, each of 7.5 feet nominal diameter. The forward chamber is used as a control room. The mating skirt is attached to the mid sphere and it, along with the aft sphere, is used for personnel transfe . The DSRV has extremely sophisticated navigation control and propulsion systems which give it the capability of locating the disabled submarine, diving to it and literally "landing" it on the mating ring (much as a helicopter lands on a pad).

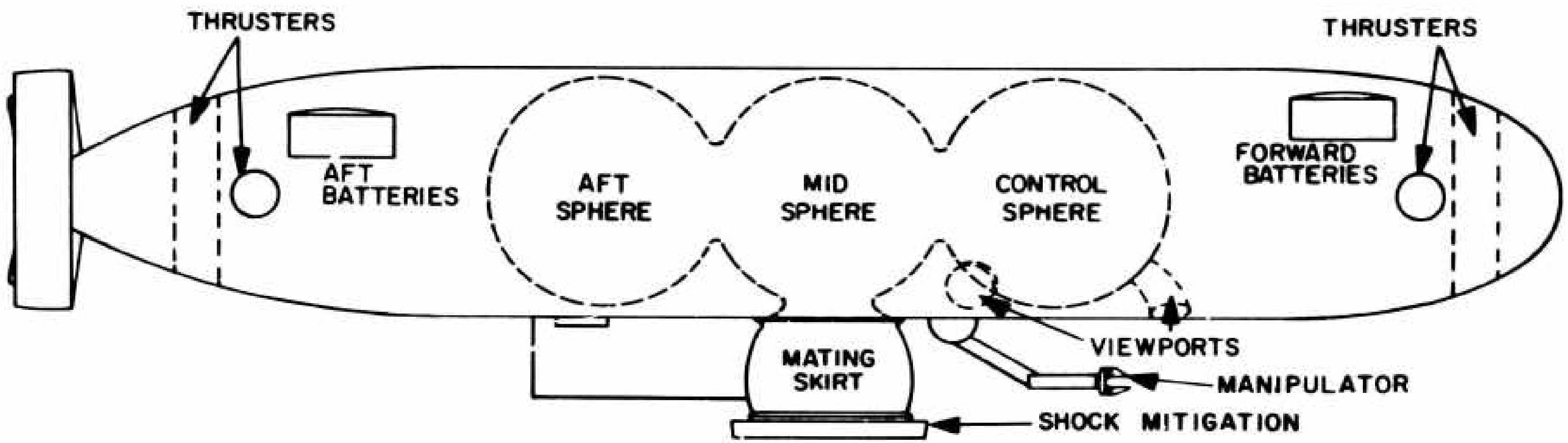


Figure 2-1. Deep Submergence Rescue Vehicle

The vehicle is controllable in roll and pitch within ± 2° over a range of 45° and hovers in this attitude. No auxiliary mating aids are required except in relatively high currents or disturbed water. If these conditions are encountered, a grapnel may be lowered from inside the skirt, hooked to a bail on the submarine escape hatch and the vehicle is then winched down to rest. A shock mitigation system absorbs energy when skirt and mating seat come in contact and limits impact loading on the seat to 40,000 pounds. As additional safety measures, the DSRV external hull is required to withstand a 0.85 foot per second velocity of impact and the mating skirt 2.0 feet per second.

2.1.2 Internal Arrangement

The attributes of the DSRV correspond to the basic requirements of a Station resupply vehicle. Although the prototype vehicle (DSRV-I) will be limited to depths of 3,000 feet, all later vehicles will have a 6,000 foot operating depth. While arrangement of the prototype vehicle does not provide sufficient internal volume or weight payload capacity to resupply the Station in one dive, subsequent vehicles could be modified by rearranging the interior of the mid and aft spheres to provide this capability. In order to adapt the DSRV for Station support, several additions to normal equipment have been designed.

2.1.2.1 Aft Sphere

The DSRV aft sphere is normally equipped with life support equipment for twelve men and a seat for these men which encircles the interior of the sphere. Since personnel will not be transferred in the aft sphere, the standard life support equipment may be removed during Station resupply. Flexible tanks for transporting potable water and sanitary waste are installed in the center space ringed by the seat (Figure 2-2). The potable water tank is installed below the sanitary waste tank so that, by pumping liquid from the Station into the waste tank, sufficient pressure is applied to the water tank to initiate siphoning action and the water drains through a hose to interim stowage tanks in the access chamber.

Dry stores will be stacked around the flexible liquid tanks. A revolving platform mounted on the existing circumferential seat provides a convenient means of loading and unloading material stocked upon it. Operating as a lazy susan, the platform can be rotated to bring material close to the inter-sphere hatch so that the loading crew is not required to clamber about the congested stowage space of the aft sphere.

2.1.2.2 Mid Sphere

The DSRV mid sphere will be used to transport the Station crews to and from the surface. This sphere normally has life support equipment sufficient for 12 men and a seat for them like that in the aft sphere. The seat will be retained for use of 5 men and their sea bags. Life support equipment for 7 men may be removed from this sphere to increase stowage volume. An electric hoist is installed above the skirt hatch to assist in the transfer of men and materials to and from the Station access chamber (see Section 6). Power for the hoist will be provided by the vehicle.

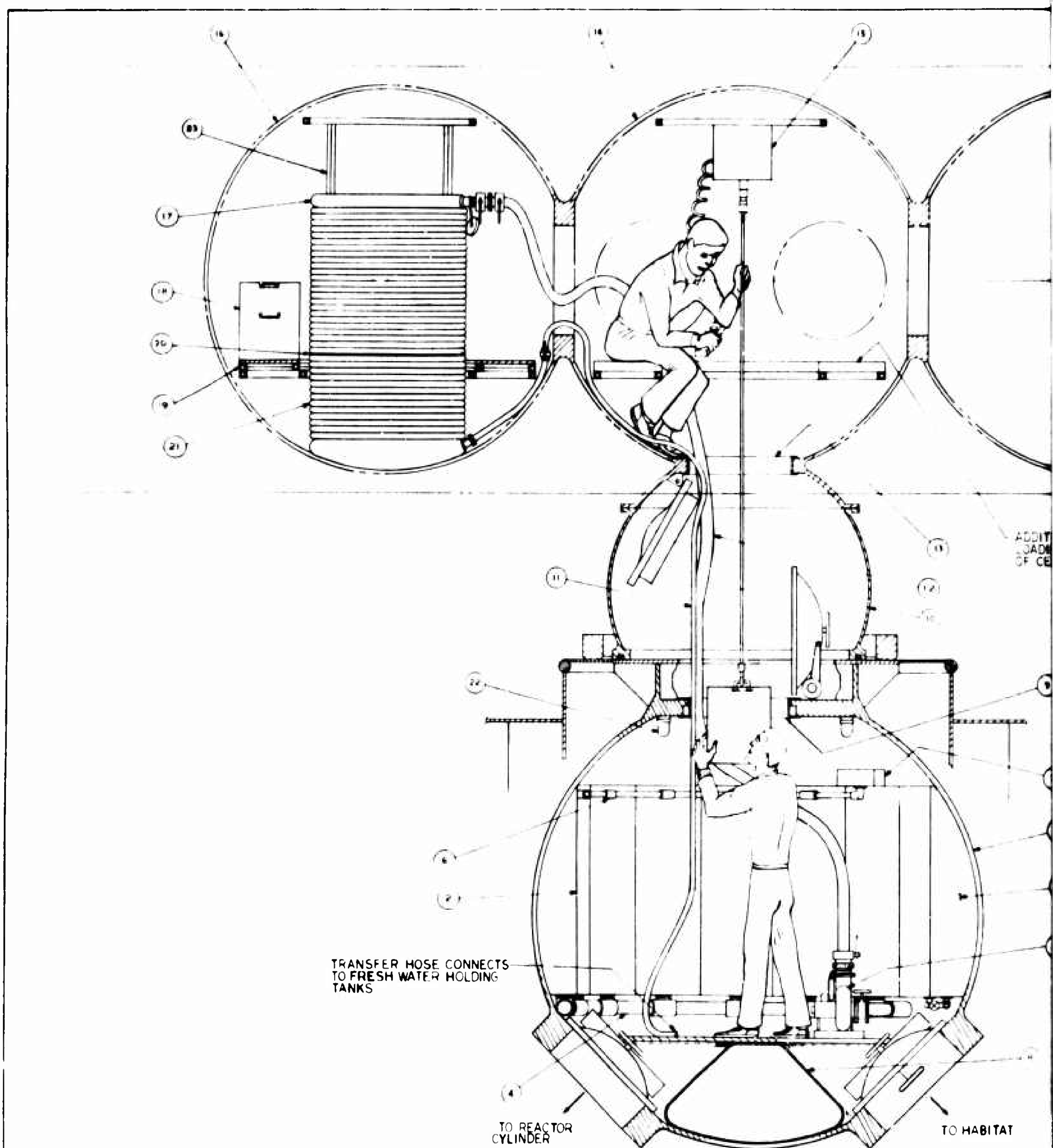
Special chests for transporting frozen food, hoses for liquid transfer, and other interface equipment are described in detail in Sections 6 and 8.

2.2 MATING MECHANISM

2.2.1 Station on Bottom

Docking and mating the DSRV to the Station will follow the same general procedure as is planned for submarine crew rescue. The Station access chamber (see Section 2.3) is equipped with a mating platform similar to that installed on fleet submarines to accommodate the DSRV. The DSRV mating skirt is fitted with a rubber gasket (Figure 2-3) which seats on the mating platform and will seal over irregularities of up to 1/8 inch.

Under normal (low current velocity) conditions the DSRV will navigate to the Station site with its standard equipment. If visibility is good, a vehicle crew member



Scale: 1 inch / 30 inches

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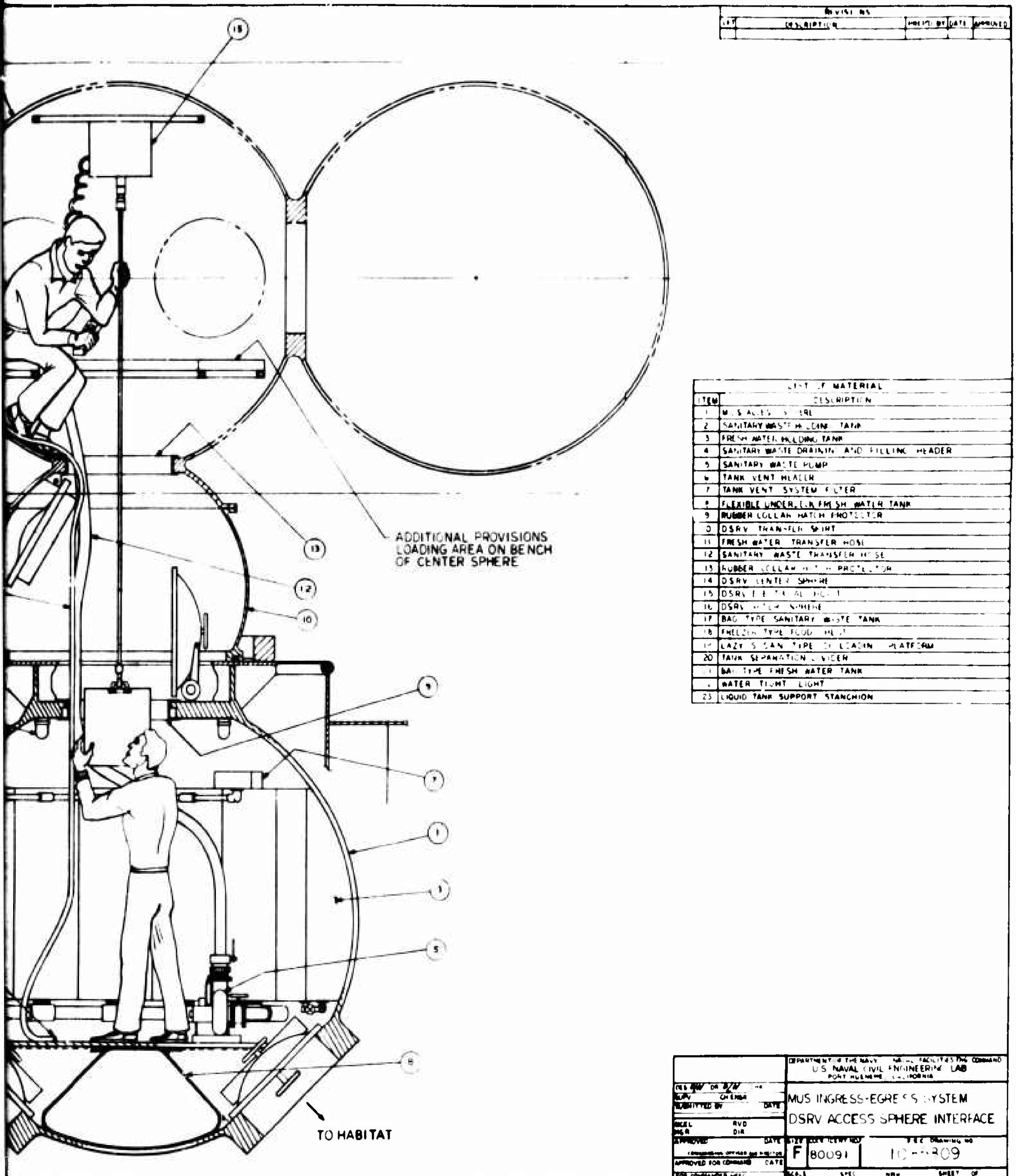

LIST OF MATERIAL	
ITEM	DESCRIPTION
1	M.U.S. ACCESS SPHERE
2	SANITARY WASTE HOLDING TANK
3	FRESH WATER HOLDING TANK
4	SANITARY WASTE DRAINING AND FILLING HEADER
5	SANITARY WASTE PUMP
6	TANK VENT HEADER
7	TANK VENT SYSTEM FILTER
8	FLEXIBLE UNDERDECK FRESH WATER TANK
9	RUBBER COLLAR HATCH PROTECTOR
10	DSRV TRANSFER SKIRT
11	FRESH WATER TRANSFER HOSE
12	SANITARY WASTE TRANSFER HOSE
13	RUBBER COLLAR HATCH PROTECTOR
14	DSRV CENTER SPHERE
15	DSRV [illegible]
16	DSRV [illegible] SPHERE
17	BAG TYPE SANITARY WASTE TANK
18	FREEZER TYPE FOOD [illegible]
19	LAZY SUSAN TYPE [illegible] LOADING PLATFORM
20	TANK SEPARATION DIVIDER
21	BAG TYPE FRESH WATER TANK
22	WATER TIGHT LIGHT
23	LIQUID TANK SUPPORT STANCHION

Figure 2-2. IES Interior Arrangement (1)

B

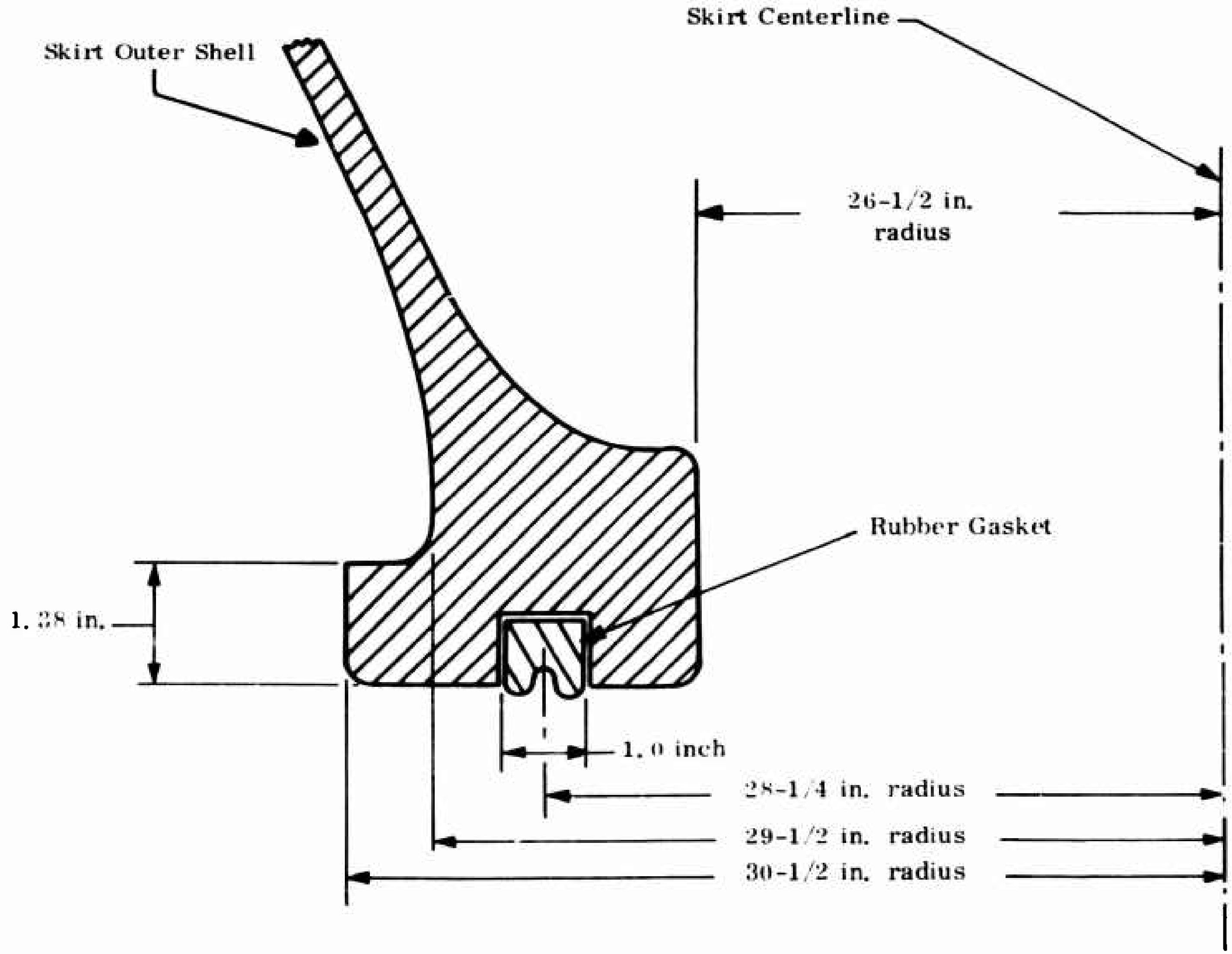

Figure 2-3. DSRV Skirt Seal

will direct docking by relaying relative position information, as seen through viewports, to the vehicle pilot. If visibility is poor a short range sonar transducer mounted near the access chamber hatch will be used in conjunction with a similar transducer mounted inside the vehicle skirt (standard equipment) to determine position.

When the DSRV is resting on the mating skirt, the water which has been trapped between skirt and access hatch is pumped to tanks on the vehicle superstructure. When the skirt cavity is dry, pressure between the vehicle mid-sphere and access hatch is equalized to one atmosphere. At this point, the vehicle is firmly held to the mating platform by the pressure differential between skirt interior and ambient water and by adjustment of the vehicle ballasting system. No holdowns are required.

The vehicle hatch is opened and the access chamber atmosphere is sampled by means of a fitting in the access hatch. If the atmosphere is acceptable, the hatch is opened, men and material transferred, and both hatches are closed. Water is pumped back into the skirt cavity and the cavity pressure equalized to ambient. The ballast system is adjusted and the vehicle returns to the surface.

Under conditions of relatively high current velocity (.75 knot is the upper restriction on the Station) if normal docking is not possible, the DSRV, using the manipulator will attach a grapnel to an access chamber hatch bale and winch itself down into position.

Mating with vehicles other than the DSRV is discussed in Section 4. Due to the great variations in submersible design it is not feasible to develop a generalized mating mechanism. The requirements for each vehicle must be determined independently.

2.2.1 Mid-Depth Tether

A requirement of the Ingress-Egress System is to provide means for safely transferring men and material into and out of the manned underwater station while the

Station is installed on the ocean bottom. In view of the possibility that the Station will have greater depth capability than the vehicles which are available to service it, it may be necessary to tether the Station off-bottom, during resupply, at a depth which accommodates vehicle capability.

Assuming that the Station will be tethered at a depth sufficient to avoid effects of surface wave action, it should not be too difficult to maintain a stable condition in the vertical plane. However, if only a single anchor line is used it is likely that rotation will occur about the vertical axis since the Station will have the same characteristics as a torsional pendulum. As the resupply vehicle approaches, pressure waves preceding the vehicle hull and vortices in the region of the vehicle propellors may be strong enough when added to torsional forces to cause Station movement.

It may be necessary to provide additional tethers well outboard from the Station to gain sufficient stability for mid-depth mating. This would in turn require more winches, cables and anchors and system complexity would increase significantly. An alternative solution is the addition of small thrusters mounted on the main ballast tanks to counteract torsional forces.

2.2.2 Observation Sphere Access

Thus far only mating to a platform located on the top of the Station has been considered. Access via the observation sphere beneath the habitat cylinder would have some advantages were it not for obstacles to vehicle maneuvering inherent in the Station conceptual design. With 30 foot legs, even with the legs in a vertical position there is only approximately 10 feet of clearance between the ocean bottom and the lower extremity of the observation sphere. There is less below the lock-in/lock-out spheres. The distance between the anchor cable and the observation sphere vertical centerline is approximately 10 feet and between the nearest leg and observation sphere (with leg vertical) 20 feet.

The significance of these dimensions becomes apparent when compared to vehicle size. Deepstar 4000, one of the smaller submersibles, is 18 feet long, 10 feet in beam and 7 feet high. The Ben Franklin (formerly PX-15) which is designed for crew comfort and has generous payload capacity is 48 feet long, 18 feet in beam and 20 feet high. Tethering the Station off-bottom increases vertical clearances, and the addition of powered mechanisms to raise the nearest leg while tethered removes that potential hazard, however, Station motion problems described above are then applicable.

An additional restriction to such a mating is the fact that no vehicles with a top hatch are equipped for mating (see Section 4). Therefore, mating to the top of the Station is the only immediate practical solution.

2.2.3 Anti-Fouling Techniques

The Station, except for early evaluation operations, will be installed at 3,000 to 6,000 feet. Fouling at the shallow depths (see Section 1.2) can be minimized by application of anti-fouling coatings to critical areas such as the vehicle mating surface. The specific treatment will depend on local conditions. Divers or small submersibles can be used to examine these areas periodically and remove troublesome organisms by hand or vehicle manipulator. Since submerged time at shallow checkout sites will be short, these precautions should not be excessively inconvenient.

At greater depths any maintenance is difficult, but fouling potential decreases (see Section 1.2). Small, soft or brittle organisms which are caught between the vehicle skirt seal and the Station mating surface will be crushed and extruded to the extent that they will not affect sealing. It is possible that larger, more resistant organisms could hinder effective sealing. These will, however, probably be more susceptible to toxic, anti-fouling substances which could be released periodically from reservoirs around the top of the access chamber.

If the use of toxic substances is inimical to Station operations (as in the case of biological studies) the resupply vehicle may be required to clear the mating surface with its manipulator prior to landing.

2.3 ACCESS CHAMBER

The Station access chamber is a spherical pressure hull with 9 foot outside diameter and 1-1/8 inch plate thickness. The sphere is interposed between the apexes of the reactor cylinder and the habitat cylinder and is connected to the two cylinders by thick forged hatch rings which are welded into the habitat and reactor cylinder hemiheads and into the spherical section of the access sphere as shown in Figure 2-4. Figures 2-2 and 2-5 show internal arrangements.

2.3.1 Hatches

A spring loaded face seal hatch to permit ingress and egress from the access sphere to the vehicle has been incorporated on a stiff foundation built into the upper part of the access sphere and under the mating platform. The hatch is, in principle, the same as used for military submarine escape hatches with the exception that is heavier, in order to provide the strength necessary for Station depths, and it will have a more sophisticated gasket system. Double operating gear is provided so that it may be opened from either side and high pressure packing is provided around the operating gear shaft so that no leaking will occur when exposed to sea pressure. Although the shaft must have a high pressure seal, the operation of the gear will only take place when it is exposed to atmospheric pressure, so that excessive binding should not occur. There will be a gas sampling and pressure equalizing valve in the hatch cover to permit sampling the atmosphere of the Station by a rescue submersible in the event that there is no evidence of life onboard, and also to be used to equalize the pressure on either side of the hatch when it is to be opened.

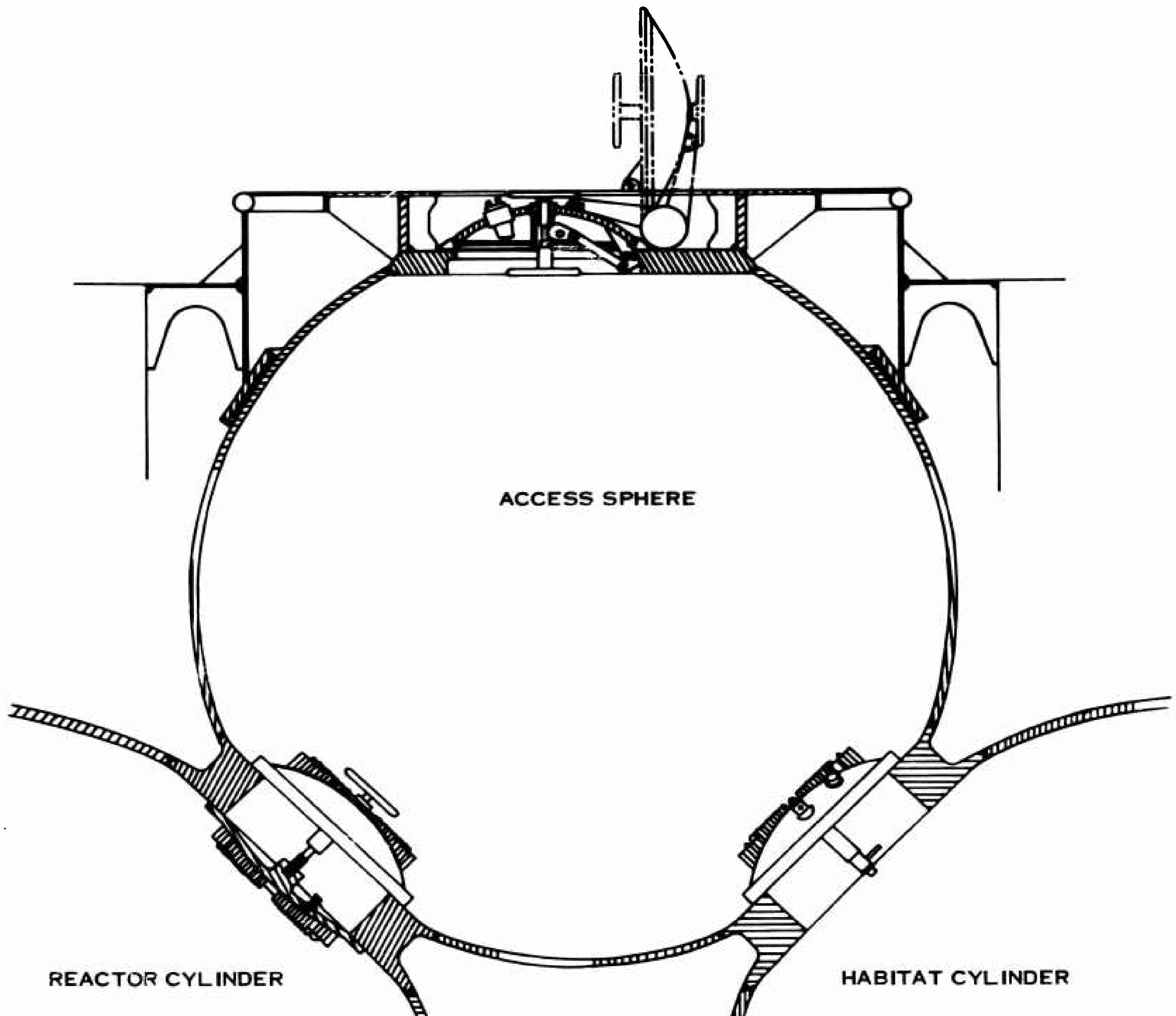

Figure 2-4. Access Sphere Construction

ITEM	DESCRIPTION
1	MUS ACCESS SPHERE
2	SANITARY WASTE HOLDING TANKS
3	FRESH WATER HOLDING TANK
4	SANITARY WASTE DRAINING & FILLING HEADER
5	SANITARY WASTE PUMP
6	TANK VENT HEADER
7	TANK VENT SYSTEM FILTER
8	FLEXIBLE UNDER DECK FRESH WATER TANK
9	FIBERGLAS HATCH PROTECTION COLLAR
10	WATER TIGHT LIGHT
11	STORES HANDLING HOIST
12	FRESH WATER TANK VENT
13	UNDER DECK TANK VENT
14	FRESH WATER TANK FILLING & EMPTYING CONNECTION
15	MUS HABITAT CYLINDER
16	STORES HANDLING CHUTE (COLLAPSIBLE)
17	VENTILLATION BLOWER AND HOSE
18	SANITARY WASTE DISCHARGE CONNECTION
19	FRESH WATER FILLING MANIFOLD
20	LADDER
21	ALUMINUM FLOOR GRATINGS
22	SANITARY WASTE TANK FILLING CONNECTION
23	BUNKS
24	FRESH WATER TANK FILLING & EMPTYING CONNECTION
25	FRESH WATER TRANSFER HOSES
26	SANITARY WASTE TRANSFER HOSE
27	
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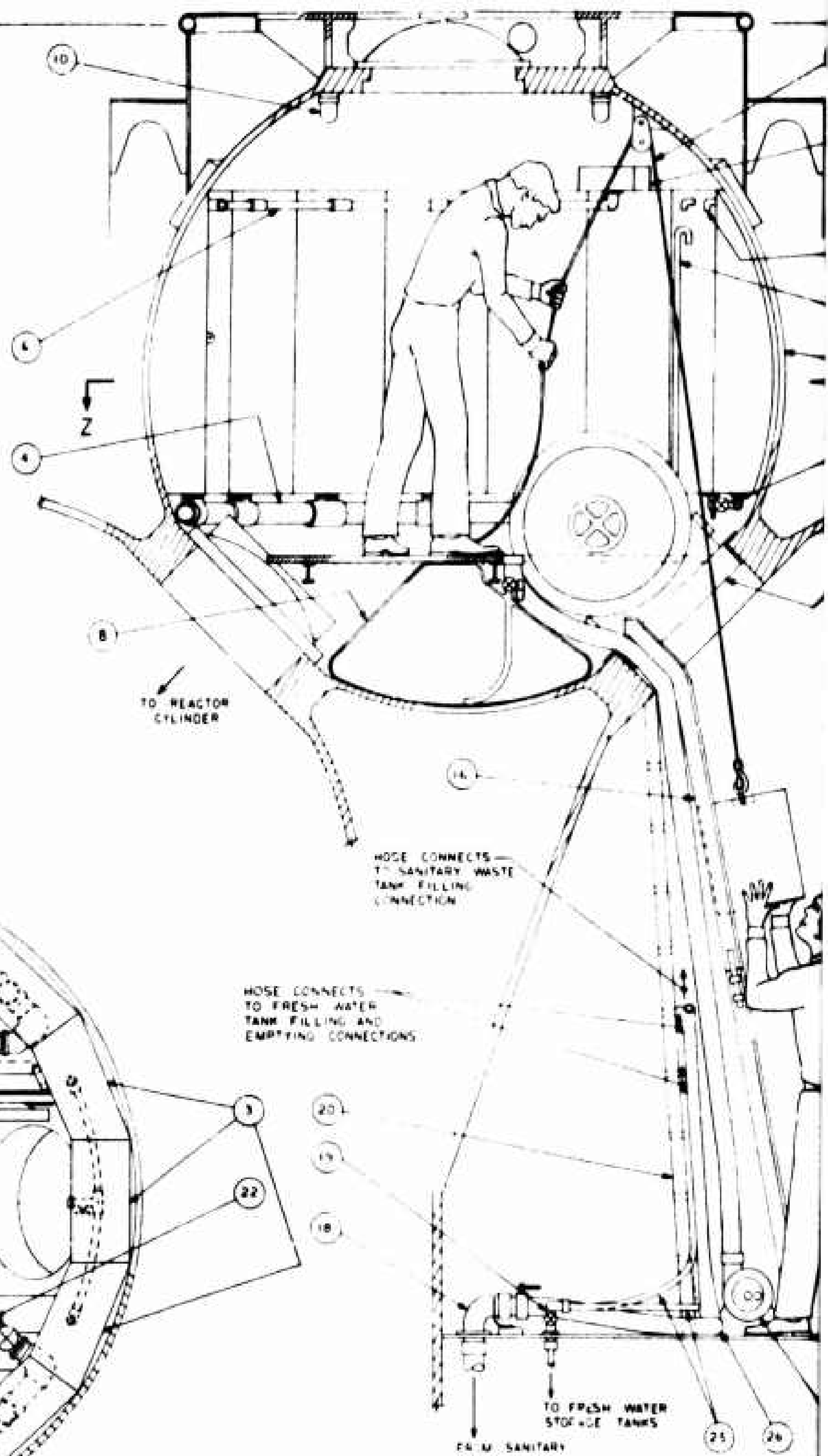

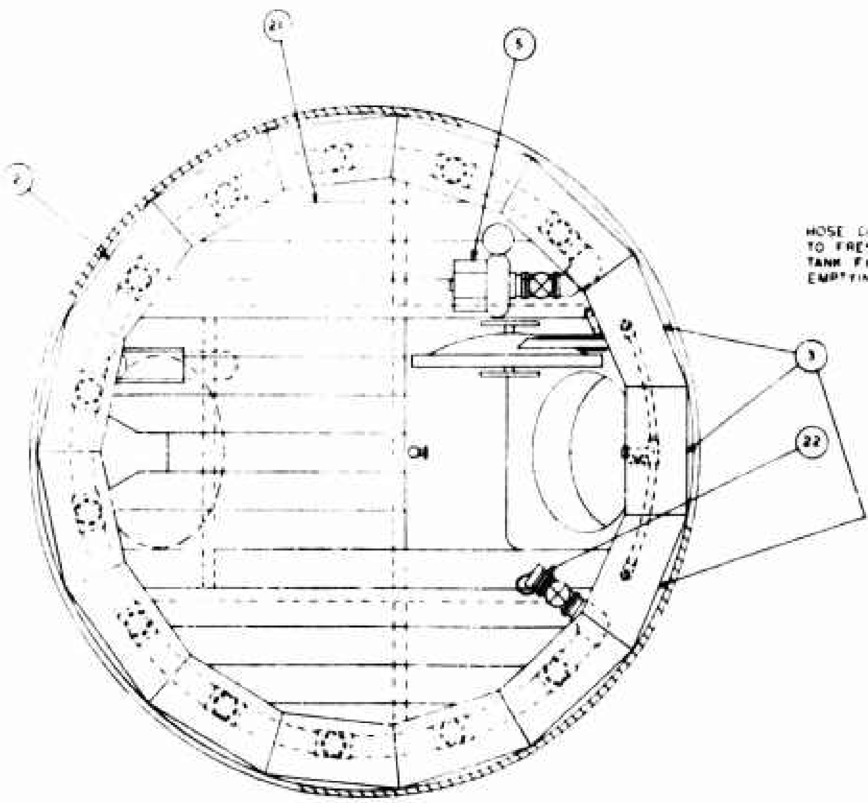

SECTION Z-Z

Scale. 1 inch = 30 inches

A

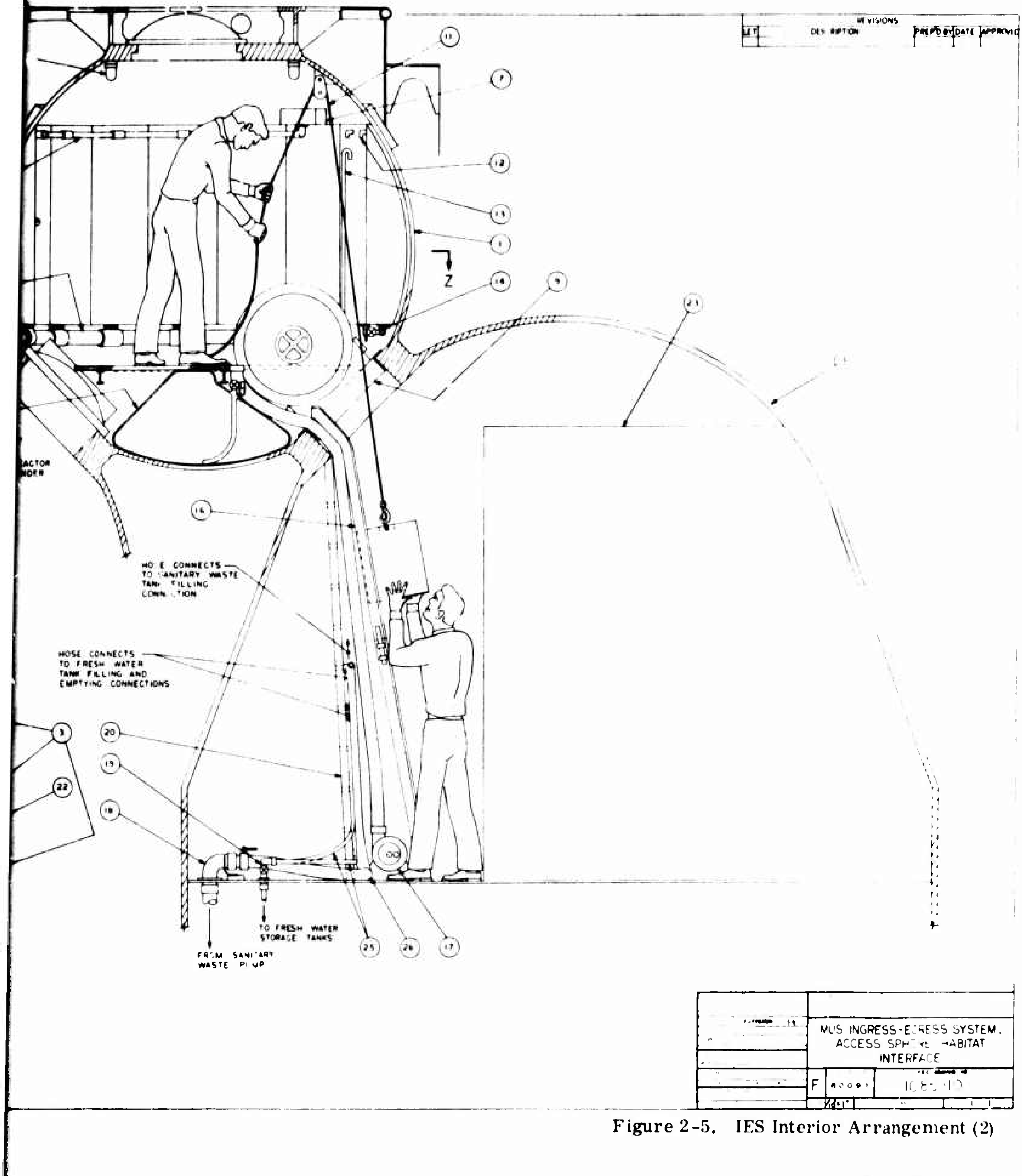

Figure 2-5. IES Interior Arrangement (2)

B

The hatches going from the access sphere into the reactor cylinder and the habitat cylinder are of the same design as the upper hatch because they too must withstand sea pressure in the event of a leak in the upper hatch or a leak while the DSRV is mated to the Station. These hatches seat on the heavy ring forgings located at the sphere-to-sphere intersections. The hatch to the reactor cylinder is a double hatch to protect against over pressure in the event of a reactor casualty. It consists of two face seating hatches face to face on either side of the boundary, and each cover resisting an increase in pressure on its own side. The hatch cover from the access sphere to the habitat contains a sampling valve for the reasons stated in connection with the upper hatch.

Analysis shows that the hatch designs developed in the General Dynamics reference report are functionally adequate. Further investigations, including detailed stress analysis of the hatch ring interface with pressure hulls must be pursued in the final design phase of Station development.

2.3.2 Decking

A deck of six inch wide aluminum grating is installed in the lower part of the access sphere. This deck has cut outs and removable sections to permit opening the lower hatches. No deck plates are installed over the hatch to the habitat because in the ingress and egress operation there will never be an occasion for covering this hatch over, and its frequent use is an essential part of the operation. On the other hand, it is unlikely that the hatch to the reactor cylinder will be opened during a replenishment operation and the space over that hatch is needed for stowage and working area, therefore, removable deck plates are provided over this hatch.

The hatch gratings are supported by a framework of I beams and angles which is contoured to fit the bottom part of the access sphere and thereby avoid any weld attachments to the sphere itself. Six feet, two inches clearance has been allowed between the deck plates and the top of the sphere.

2.3.3 Storage Tanks

Tanks for interim storage of potable water and sanitary waste are installed in the access chamber, which is utilized as a lock-in/lock-out chamber during Station cargo and personnel transfer operations. Part of this storage capacity is provided by a belt of tanks arranged around the interior of the chamber. These tanks are divided into "orange slice" segments so that each can be installed and removed through the access hatch. Fifteen tank segments in all are provided, twelve of which are used for sanitary waste, and the other three for fresh water.

These liquid tanks around the inside of the access sphere are designed so that their inner faces are perpendicular to the edge where the floor meets the shell of the sphere. Thus, these tanks do not encroach on the available working space, which is roughly cylindrical, a little over seven feet in diameter and a little over six feet in height. The tanks are held in place by bolting them together so that they form a hollow spherical segment which is self supporting because it fits the internal spherical contour of the access sphere and thus makes welding to the sphere unnecessary.

In the plan view, all the tanks are keystone shaped with the exception of the center fresh water tank which has parallel sides. This geometry will assist in holding them in place, it being impossible to remove any of the tanks until the center fresh water tank has first been removed.

Additional fresh water is contained in a bag type tank under the floor plates. This tank is made flexible so that it can be collapsed and taken in and out through the access sphere hatch.

Details of access chamber equipment may be found in Section 8.

2.3.4 Life Support

During resupply operations the access chamber, except for brief periods of

less than 5 minutes, will be open to either the vehicle or the Station habitat via 25 inch diameter hatches. Sufficiently fresh air will be circulated about the access chamber by the life support systems of these two adjacent bodies to preclude the necessity of a separate system permanently installed in the chamber.

Just prior to the time the resupply operations are scheduled to begin a blower and flexible ducting will be installed to ventilate the access chamber. This will exhaust stale air which has accumulated, and may be used for cooling and ventilating at anytime necessary for crew comfort.

2.3.5 Power Requirements

The total power requirement to operate access chamber lighting and sanitary waste transfer pump is approximately 1 kw at 120 volts, single phase, 60 hertz. This power is supplied from the reactor cylinder through a bulkhead connector in the connecting hatch.

2.3.6 Communications

2.3.6.1 Interior

Communications between the access chamber and the habitat will be accomplished by means of a cable link to the Station intercom system. Penetration into the access chamber will be through the connecting hatch with a waterproof, pressure resistant connector.

2.3.6.2 Exterior

Communications between the Station and the resupply vehicle or support ship will normally be via the Station underwater telephone system. If for any reason telephone communication is not possible, contact will be reestablished by means of the Station remote anchored buoy which contains telephone and radio frequency circuits. The vehicle and support ship must be fitted with the necessary interfacing equipment.

2.3.7 Safety and Warning Devices

If during the mission cycle a leak develops in the normally unattended access chamber, a warning system announces the fact to the Station crew. Several sensors which detect the presence of water are installed near the bottom of the access chamber so that if any one of them detects water accumulation an audible alarm is sounded throughout the Station and indicators on the environmental monitoring console identify the problem.

2.3.8 Lighting

The only lighting necessary for the IES is interior lighting for the access chamber. This is provided by two water tight 120 volt AC light fixtures with a 100 watt lamp in each. Each fixture is fitted with a wire mesh safety guard.

2.4 RESUPPLY PLAN

A typical sequence of operations is presented describing the steps required to resupply the Station with the DSRV. It is assumed in the sequences that the Station emplacement site is within 24 hour transit radius of a port facility that can dock the ASR-21 support ship and has crane capacity to load and unload the DSRV aboard the support ship.

1. At the port facility, the DSRV and the replacement crew and supplies for the Station mission extension are loaded aboard the support ship.
2. Preliminary checkout of the DSRV systems is performed.
3. Support ship leaves port for Station site.
4. Support ship navigates to area above Station location and establishes communication with Station crew via underwater phone.
5. DSRV is readied for first provisioning deployment and loaded with supplies, food, and water and crew.
6. Support ship launches the DSRV and monitors its progress in the descent to Station.

7. DSRV homes on Station active transducer and navigates to within optical range.

8. DSRV lands on Station mating platform and adjusts ballast.

9. DSRV dewaters skirt, pumping skirt water into transfer tanks and equalizes skirt cavity pressure to one atmosphere.

10. Vehicle personnel opens vehicle hatch and equalizes pressure between the vehicle and access sphere using gas sampling valve.

11. Replacement crew member No. 1 (R-1) opens access chamber hatch and enters chamber.

12. R-1 passes vehicle ends of sanitary waste (SW) and potable water (PW) hoses to R-2 in vehicle.

13. R-2 attaches hoses in vehicle.

14. R-1 starts SW pump.

15. Sanitary waste and potable water transfer begins.

16. R-2, R-3 enter access chamber.

17. R-4, R-5 begin passing food chests to access chamber.

18. When all 21 food chests are in chamber, R-1 turns off SW pump.

19. R-4 disconnects SW and PW hoses and passes to access chamber.

20. R-1 closes access chamber hatch and opens habitat hatch.

21. R-1, R-2 enter habitat.

22. R-3 begins passing food chests to habitat. Food chests are passed by R-1, R-2, and outgoing crew to refrigerator.

23. When all 21 food chests are in habitat R-3 closes habitat hatch, opens access chamber hatch.

24. If liquid transfer has not been completed R-3 passes hose(s) to R-4 in vehicle for attachment.

25. R-4 and R-5 begin passing chlorate candles, lithium hydroxide canisters and remaining miscellaneous stores to access chamber.

26. When all stores are transferred to access chamber liquid hoses are disconnected (if necessary) and 5 sea bags are loaded into access chamber.

27. R-4, R-5 enter access chamber.

28. R-4 closes access hatch, opens habitat hatch.

29. R-3, R-4 enter habitat.

30. R-5 passes PW hose end to habitat for attachment.

31. R-5 begins transferring cargo to habitat.

32. When all cargo is in habitat R-5 enters habitat.

33. Outgoing crew member No. 1 (0-1) enters access chamber.

34. Expended canisters and candles are loaded into access chamber with outgoing sea bags and miscalienous cargo.

35. 0-2 and 0-3 enter access chamber.

36. PW hose is disconnected in access chamber and passed to habitat.

37. 0-1 closes habitat hatch and opens access hatch.

38. 0-1 and 0-2 enter vehicle.

39. 0-3 begins passing cargo to vehicle.

40. When all cargo is out of access chamber 0-3 closes access hatch and opens habitat hatch.

41. Food chests filled with refuse are loaded into access chamber.

42. When all chests are loaded 0-4 and 0-5 enter access chamber.

43. Habitat hatch is closed, access hatch is opened.

44. Food chests are loaded into vehicle.

45. 03, 0-4, 0-5 enter vehicle.

46. Access hatch is closed.

47. Vehicle hatch is closed.

48. Vehicle skirt is rewatered and pressure is equalized.

49. Vehicle ballast is adjusted.

50. Vehicle ascends to surface.

Figure 2-6 is a simplified flow chart of the resupply plan. Approximately 4 hours is required for resupply from vehicle arrival to vehicle departure.

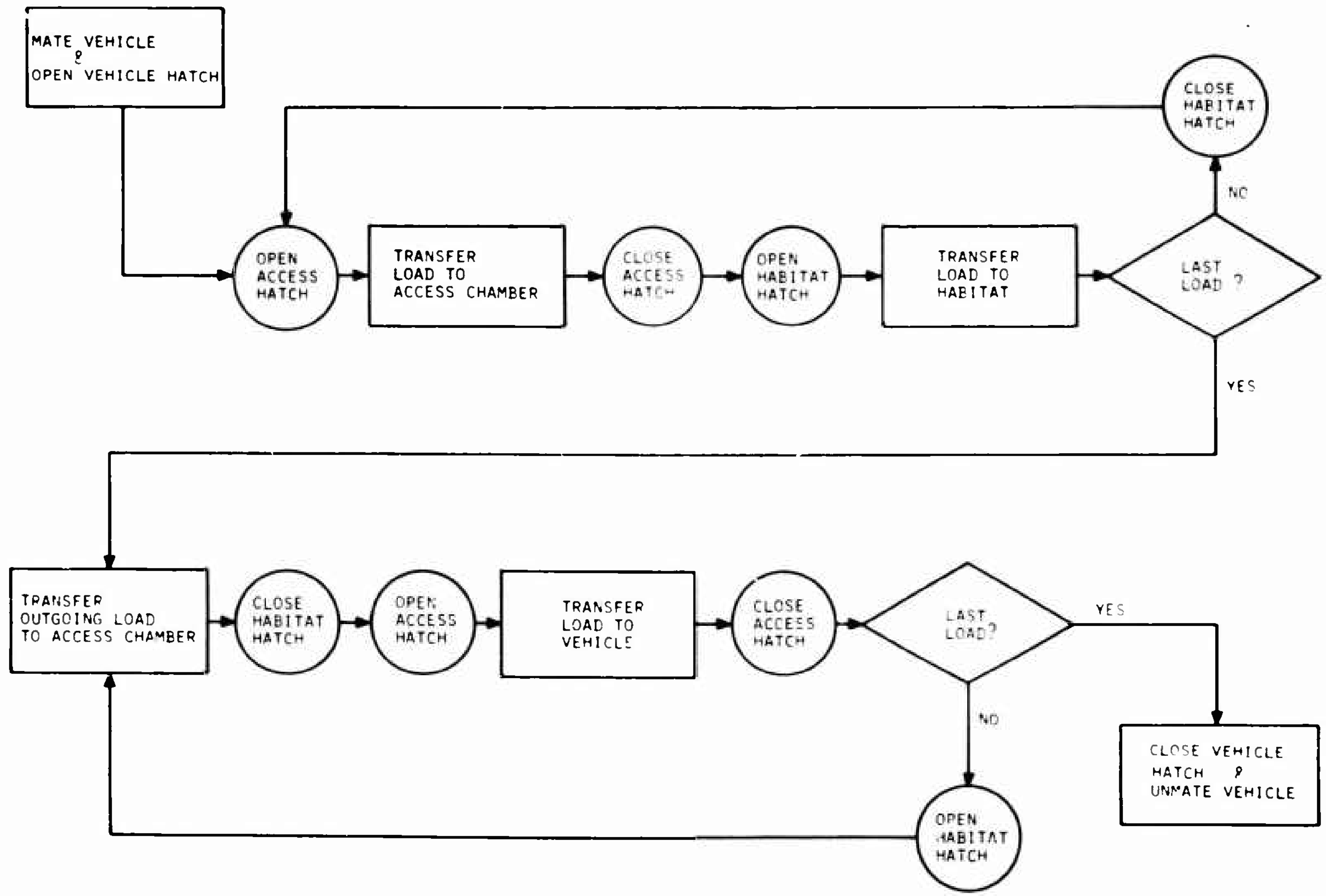

Figure 2-6. Simplified Flow Chart of the Resupply Plan

2.5 SURFACE SUPPORT SHIP

An ASR-21 will support the DSRV during resupply operations. The vessel will transport the DSRV to and from the operational site, launch and retrieve the vehicle and track it during ascent and descent keeping constant communications contact.

The ASR (Figure 2-7) has a catamaran hull with center well and elevator amidships which permits vehicle handling at a point of minimum motion. The vehicle can be launched and recovered without swimmer assistance by utilizing a system of retrieval cables from the vessel and guide arms on the vehicle which align and position the DSRV to the lift points of the elevator cradle.

The ship is equipped for vehicle repair and maintenance, and has special underwater tracking equipment and station-keeping capabilities superior to those of conventional support ships.

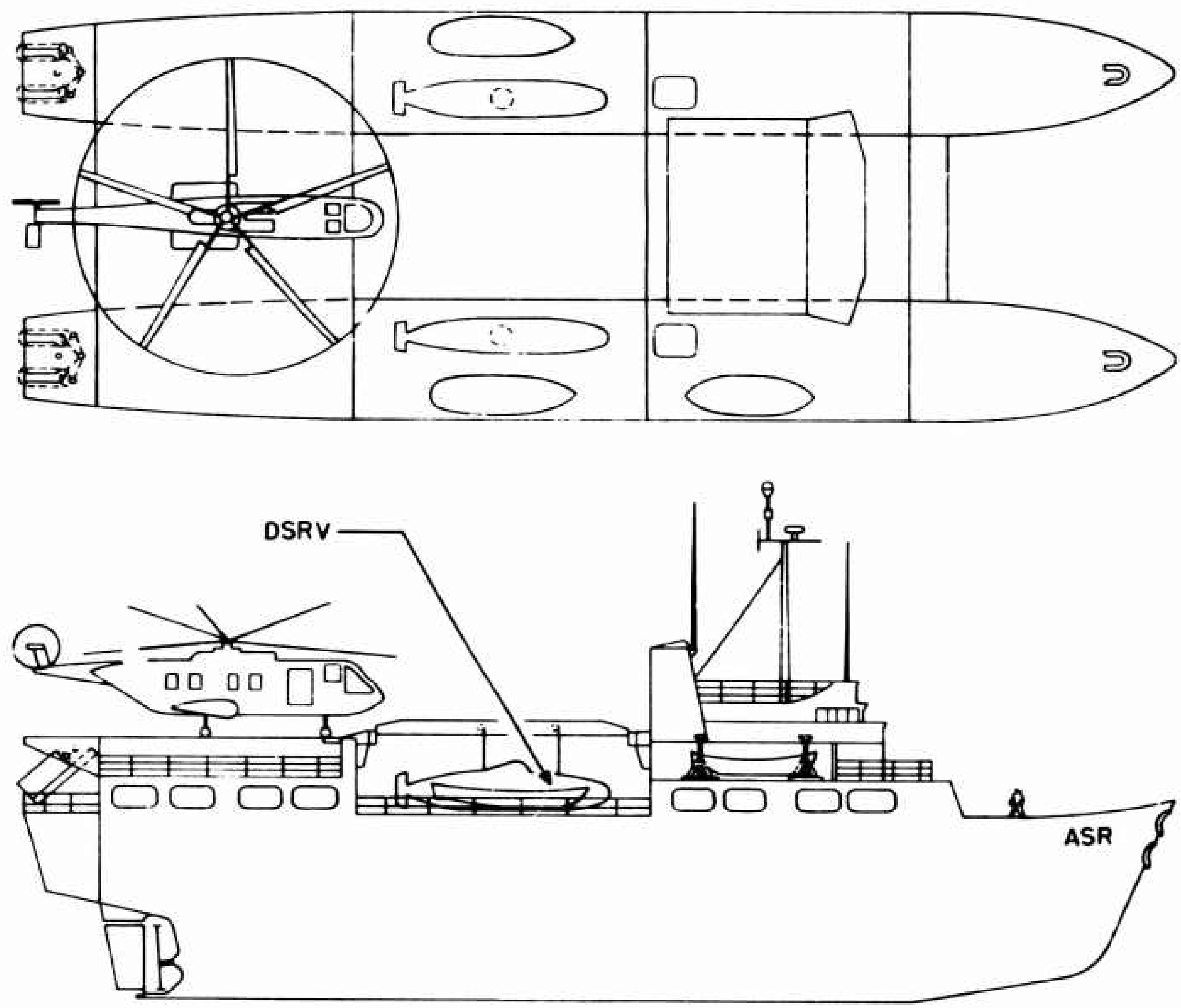

Figure 2-7. DSRV Support Ship

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3.0 SITE ENVIRONMENT

3.1 SITE CRITERIA

No site has been chosen for Station emplacement. However, candidate site areas have been selected and environmental data from these areas have been compiled to indicate typical conditions. The candidate sites were selected on the basis that the station should be located:

1. In the Pacific ocean, reasonably accessible to NCEL personnel;
2. In an area with depths of 3,000 to 6,000 feet;
3. On the leeward side of an island to provide protection from prevailing waves and weather;
4. In proximity to shore based power and logistic support;
5. Outside of regularly used missile and ordnance splashing areas;
6. Outside of submarine operating and weapons tracking areas;
7. Outside of chemical, explosive and radioactive waste dumping areas;
8. Where probability of seismic disturbance is sensibly low;
9. In areas where topography has average slops of 15 degrees or less;
10. Where bottom topography, composition and bearing strength is such that extensive foundation preparation such as piles, anchors and excavations are unnecessary.

Expanding the above criteria, it is reasonable to assume that the Station site should be located close to a major naval base, preferably one which is somewhat oriented to undersea activities and which has facilities for handling and repairing (if necessary) the Station. Cold surface water and ice conditions, high velocity currents, areas of complex and severe sea states subjected to hurricane or typhoon weather should be avoided. Heavily traveled shipping lanes, popular commercial fishing areas, nuclear test areas (past and future) are also undesirable.

It is impossible to select the optimum site or sites with all these attributes without extensive investigations, oceanographic surveys of specific sites and detailed studies. However, three areas have been chosen which are known to have a number of the desirable characteristics:

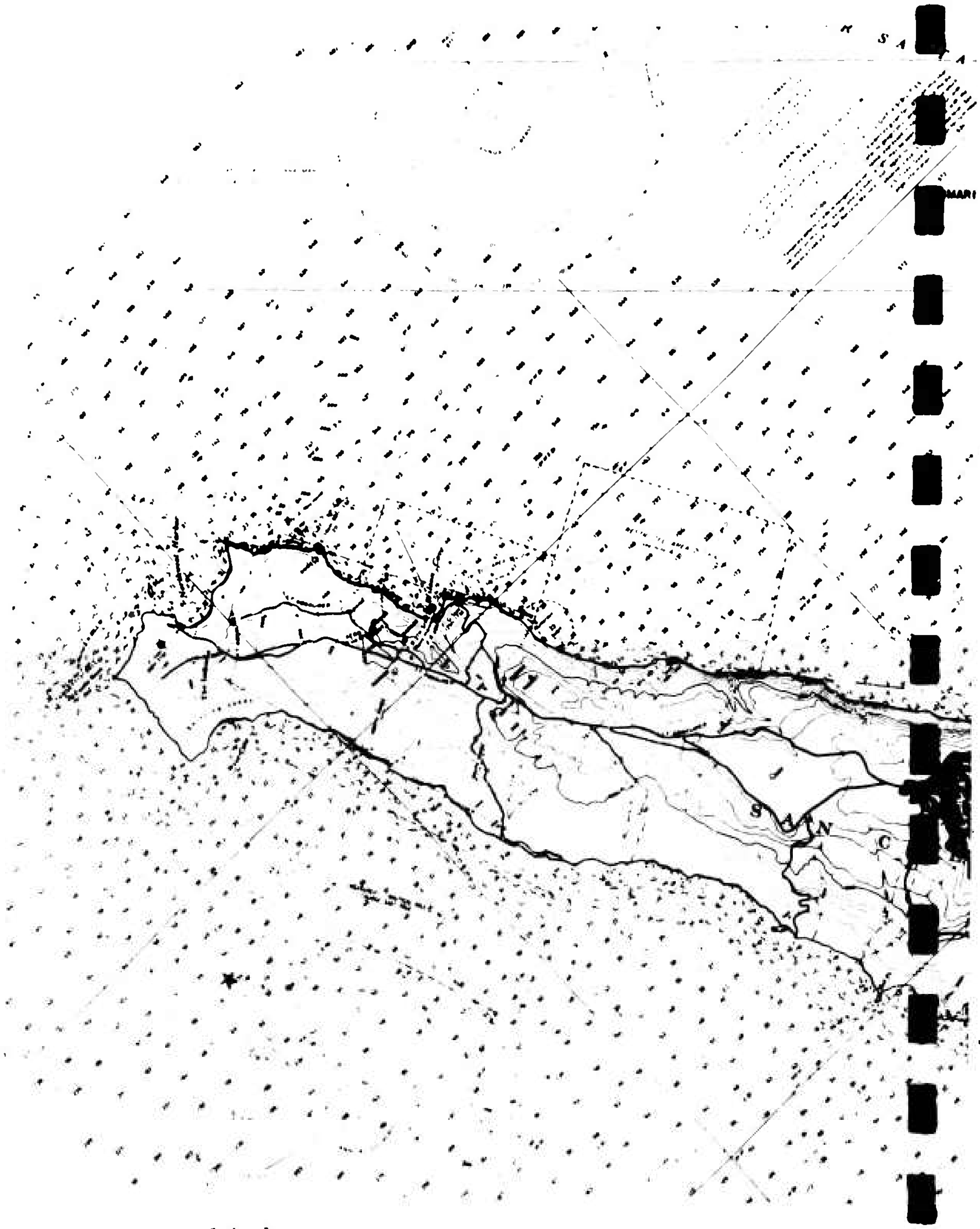
1. San Clemente Island and adjacent basin.
2. The northwest side of Kauai.
3. The southwest side of the island of Hawaii.

All three of these areas are in the Pacific, have water depths to 6,000 feet, are on the lee side of islands, and are close to shore based support. Detailed descriptions of these areas are contained in Sections 3.2 to 3.5.

3.2 SAN CLEMENTE ISLAND AREA

Located 43 nautical miles southwest of Point Fermin and 57 nautical miles northwest of Point Loma, California, San Clemente Island is 18 nautical miles long in a northwest direction, has a maximum width of 4 miles and maximum elevation of 1965 feet above sea level. It is a U.S. Naval Reservation, closed to the public. The offshore area is dangerous to vessels due to gunfire, bombing, rocket firing, and a number of special ordnance tests (see Figure 3-1).

San Clemente Basin is an irregularly shaped depression, the floor of which extends approximately from 32°15' to 32°40'N and 118° to 118°10'W. The mid-point of the basin is about 25 miles southeast of the southern tip of San Clemente Island (see Figure 3-2).



1 inch

1.4 n.m.
(Reduced Scale)

A

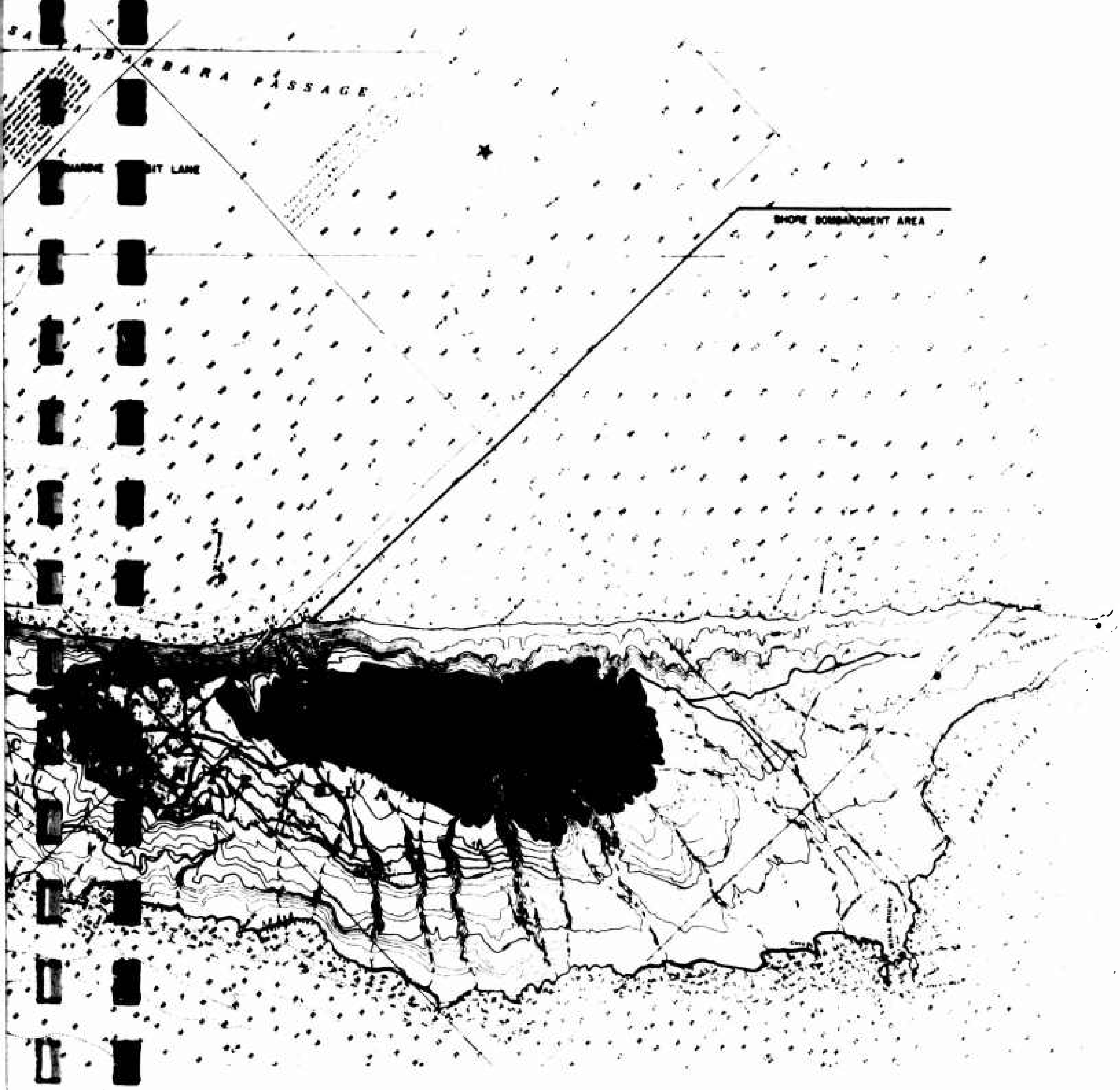
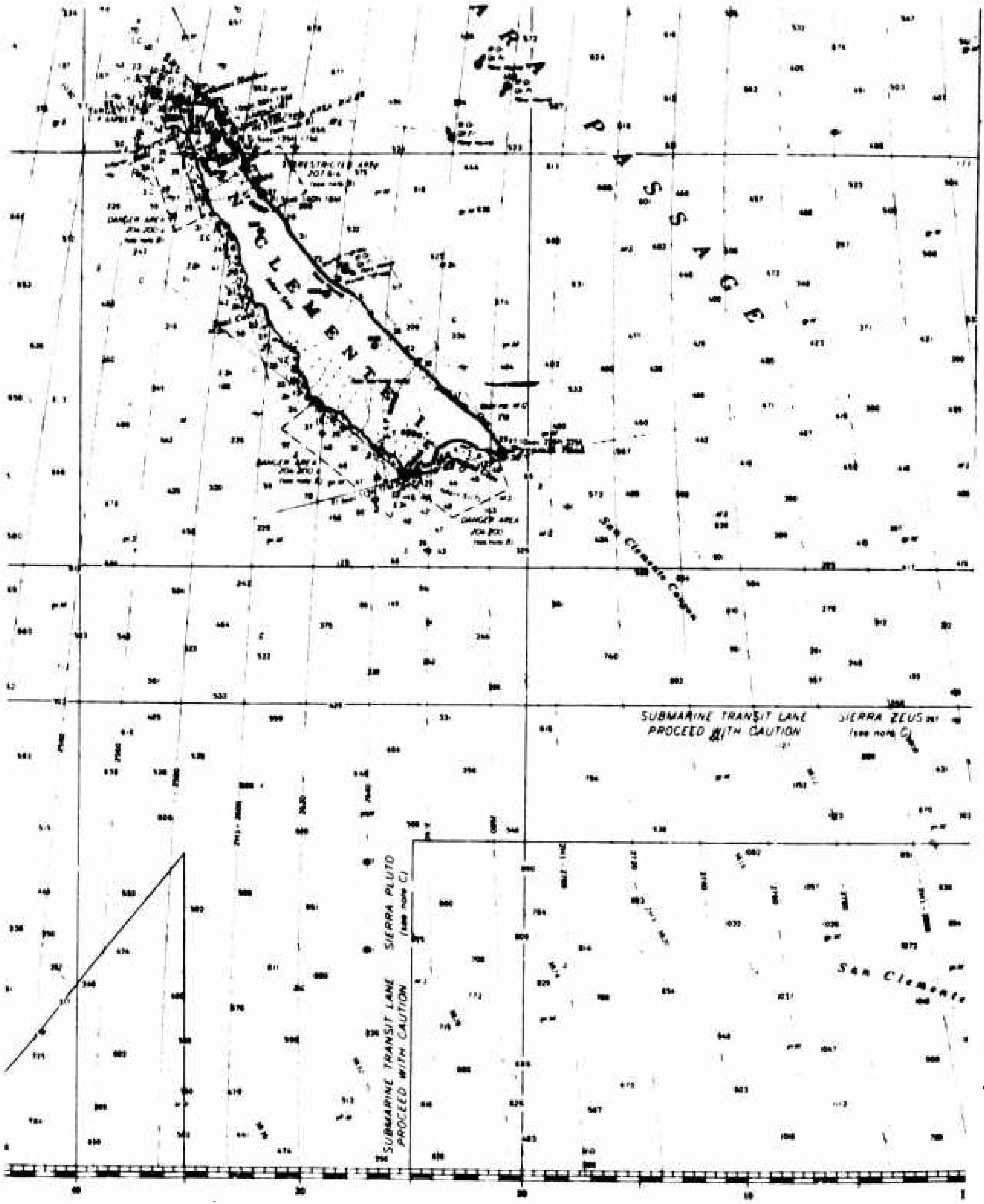


Figure 3-1. San Clemente Island

13



1 inch

5.8 n. m.
(Reduced Scale)

A

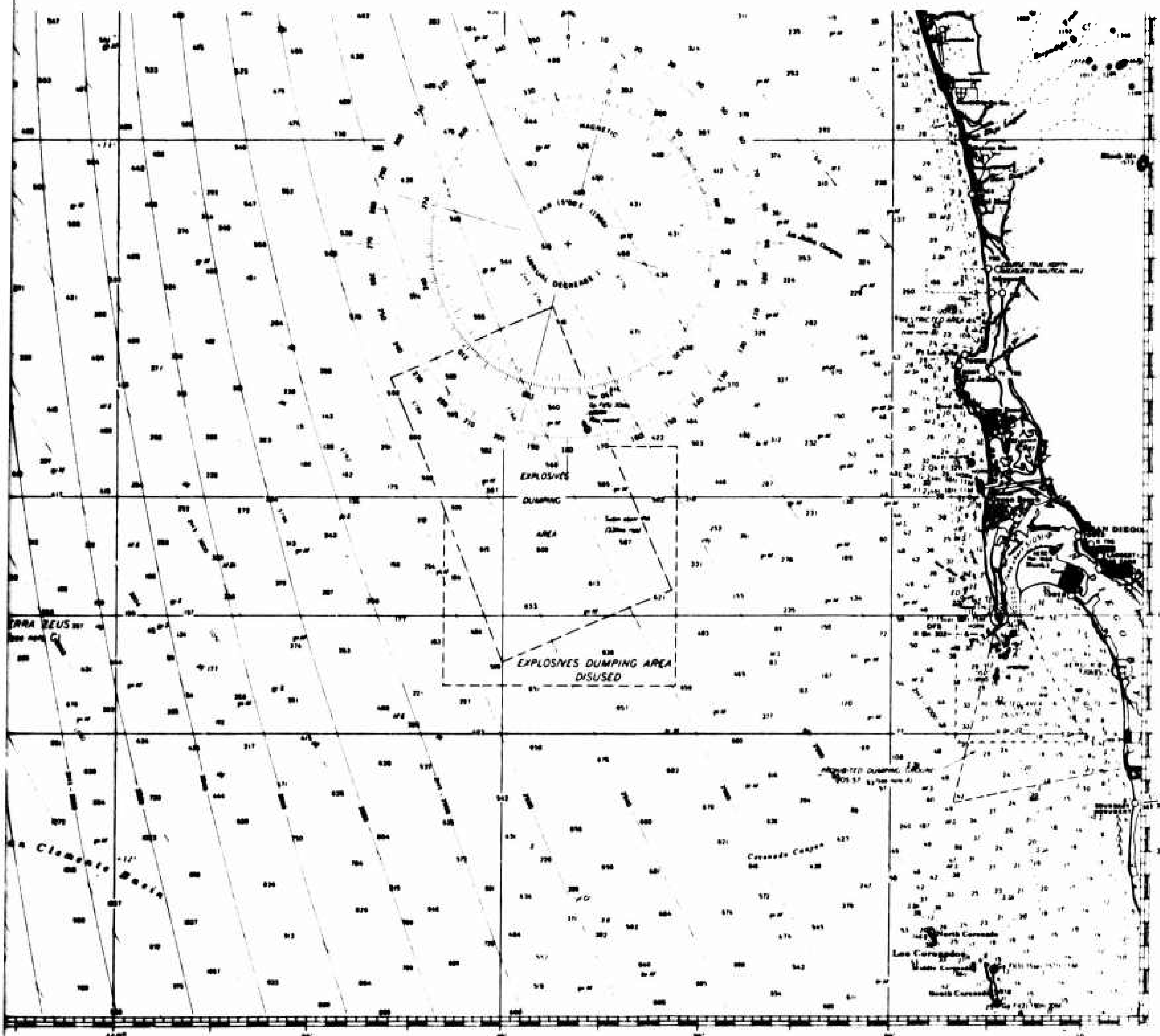


Figure 3-2. San Clemente Basin

B

3.2.1 Climatology (Linberg Field, San Diego)

Air temperature, monthly average: January 63, April 59, June 65, September 67 (°F)

Total precipitation: 12.37 inches

Mean wind speed: 5.7 knots from west

Heavy fog: 52 days per year

Mean surface water temperature (San Clemente): January 60, May 62, August 66, November 64 (°F)

Mean surface salinity (San Clemente): January 33.5, May 33.5, August 33.5, November 34.0 (0/00)

3.2.2 Weather

Weather is controlled by the Pacific High which is responsible for stable conditions along the California coast. The North Pacific High reaches greatest development in summer, its center in July being located in the latitude of San Francisco at 150°W. In October, the High contracts, centered at 30°35°N, 135°-140°W. In spring, there is a gradual return to summer patterns. Along the California coast south of 40°N, prevailing winds are northwest during the greater part of the year about parallel to the coast. Average velocity of winds off the ocean is generally low during most of the year. Gales are most frequent in the winter averaging 1% of the time off California. These gales may occur from any direction, but more often are from southeast, south, southwest than all other directions combined. Few or none come from northeast or east. In summer, the infrequent gales are mostly from northwest or east. Observations made over a period of years during all season indicate that 90% of the time the sea state in the area is 2 or less on the Douglas Sea Code (waves 1-3 feet high, see Figure 3-3). Santa Ana winds of up to 50 knots occur as off-shore winds in the vicinity of San Pedro Bay in late autumn or in winter. These winds may extend out to sea almost 40 miles. Some effects of these winds are felt on San Clemente. South of 35°N gales are very infrequent, being recorded in only 1% of operations in January and December.

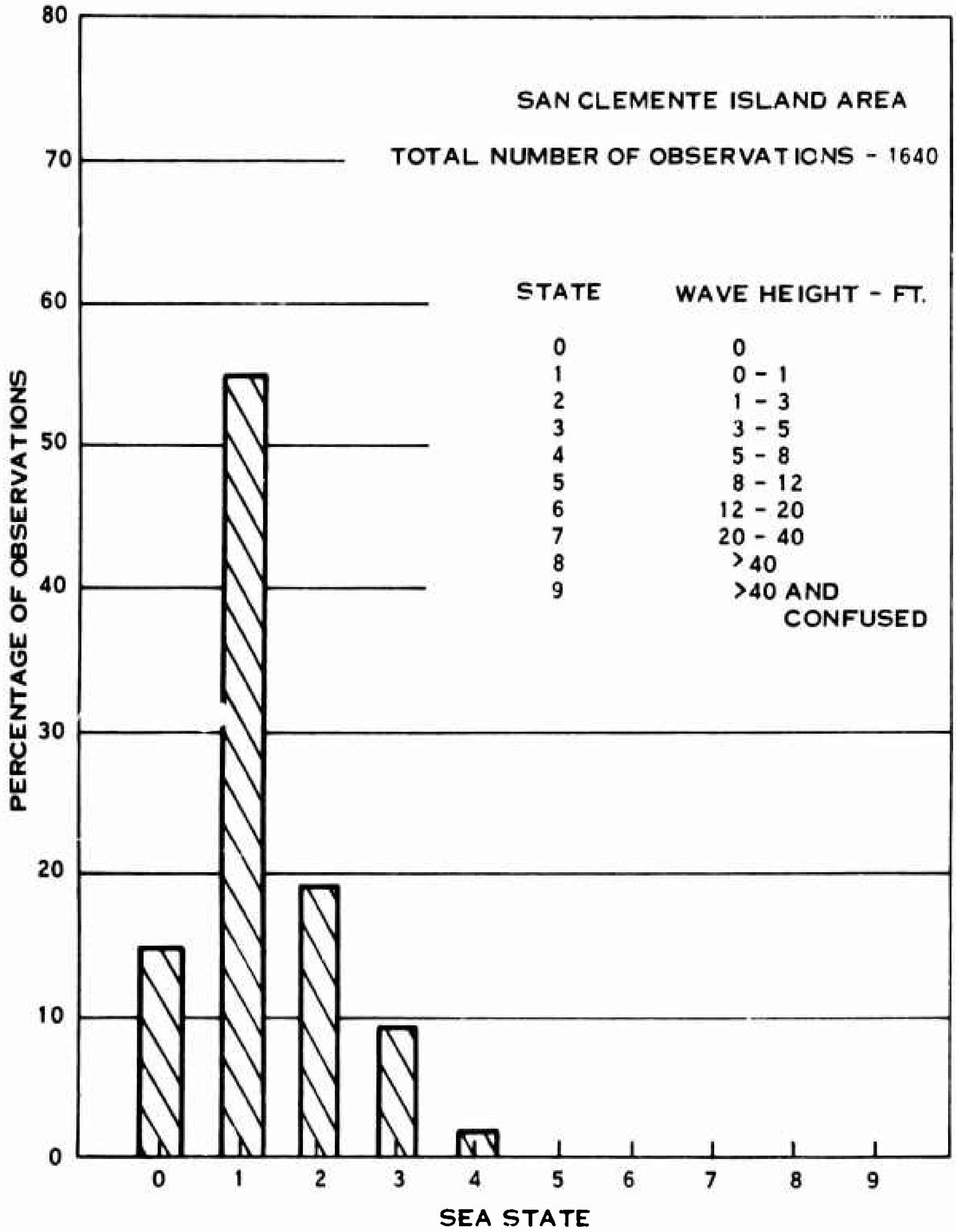


Figure 3-3.

Sea State vs. Percentage Of Observations

San Clemente may be affected by tropical storms originating in or near the Gulf of Tehuantepec in late summer or autumn. Averaging eight storms per year, few reach northern California waters but do bring squally, rainy weather to Southern California.

Fog occurs summer and winter, with summer type more frequent and extensive but not so dense as in winter. Most of the year the waters off the coast are cooler (50-60°F) than those further to westward (60-70°F) with July-August-September having the greatest differences. Cooling effect of these coastal waters on the easterly moving air above it is a cause of the prevailing fogs. The seaward extent of fog varies greatly. A band of densest and most frequent fog occurs over a narrow stream of colder water just off the coast and is frequently limited to a band of 50 nautical miles or less. At other times, fog covers large areas and may extend for hundreds of miles to seaward. On the lower California coast, from Los Angeles south, foggiest months are September, October, November, December, January, February; least foggy are May, June, July, August. There are two very foggy spots off the coast of Los Angeles: San Miguel Island and Catalina Island, both northwest of San Clemente Island

3.2.3 Coasts and Harbors

The northeast side of the island is bold with rocky cliffs. Water is generally deep inshore and kelp grows to the beach. The southwest side of the island is more irregular, but lower and has more gentle slopes. On this side, kelp grows out to or beyond the fathom 10 curve. Rocks are numerous close inshore and inside the kelp beds, but outside the kelp the bottom has a more gradual slope than on the northeast side of the island. Pyramid Cove, at the southern extremity, provides good anchorage shelter during northwest weather.

Wilson Cove, with restricted anchorage, has a long pier and some cargo handling facilities.

San Diego, some 60 miles southwest of the island provides shelter in all weather.

3.2.4 Restricted Areas

The northeast coastal area below 32°55'N is used for shore bombardment by the U.S. Navy. This area must be kept clear out to the 3600 foot depth. The coast along 32°58'N to about 33°N is restricted for use as test range. Above 33°N to 33°01'N is a restricted anchorage area (see Figure 3-1).

The off-shore area from the 3,600 foot depth is a submarine transit lane. This lane runs parallel to the island along its entire length.

3.2.5 Tides

There is a large inequality in heights of the two high waters and of two low waters of each day. On the outer coast the average difference between the heights of the two high waters of the day is from 1 to 2 feet; of the two low waters from 2 to 3 feet. The rise of tide above the plane of reference is about 5 feet.

3.2.6 Surface Currents

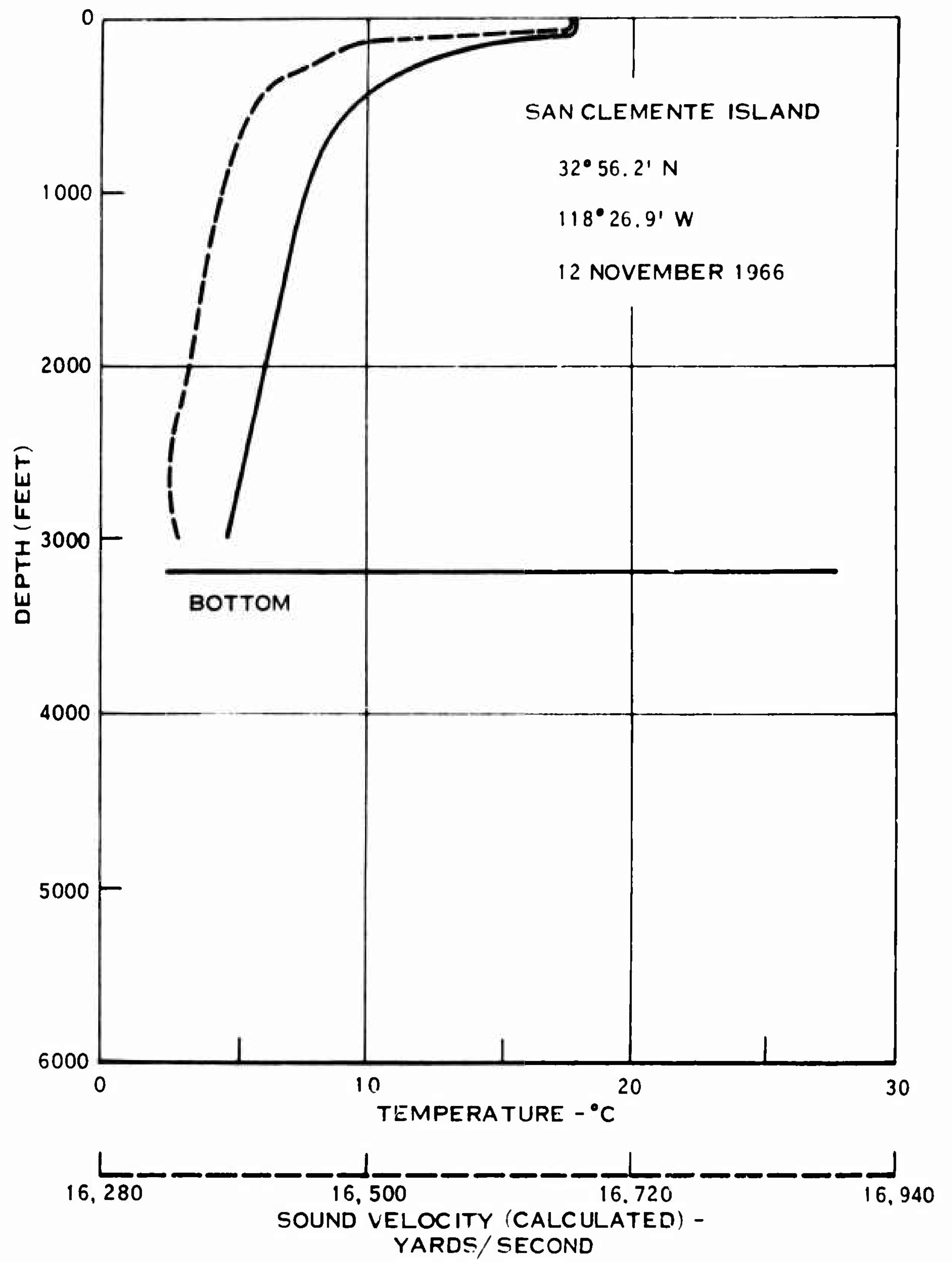
The California Current, whose outer limit is about 300 miles offshore, flows about parallel to the island. The general direction is southward, average velocity 0.2 knot (may be 1/2-3/4 knot). It is influenced by prevailing winds.

3.2.7 Water Column

Temperature, sound velocity, salinity, and sigma-t (density) profiles for the island and basin areas have been tabulated. Typical curves drawn from tabulated data are shown in Figures 3-4 to 3-7. In each case, data for curves was chosen for geographic location closest to 6,000 (or 3,000) foot contours in areas of interest.

3.2.8 Bottom Currents

Bottom currents have been measured at points off the island and in the basin. Results are tabulated in Table 3-1.



SAN CLEMENTE ISLAND
32° 56.2' N
118° 26.9' W
12 NOVEMBER 1966
BOTTOM
DEPTH (FEET)
0
1000
2000
3000
4000
5000
6000
0
10
20
30
TEMPERATURE - °C
16, 280
16, 500
16, 720
16, 940
SOUND VELOCITY (CALCULATED) - YARDS/ SECOND

Figure 3-4.

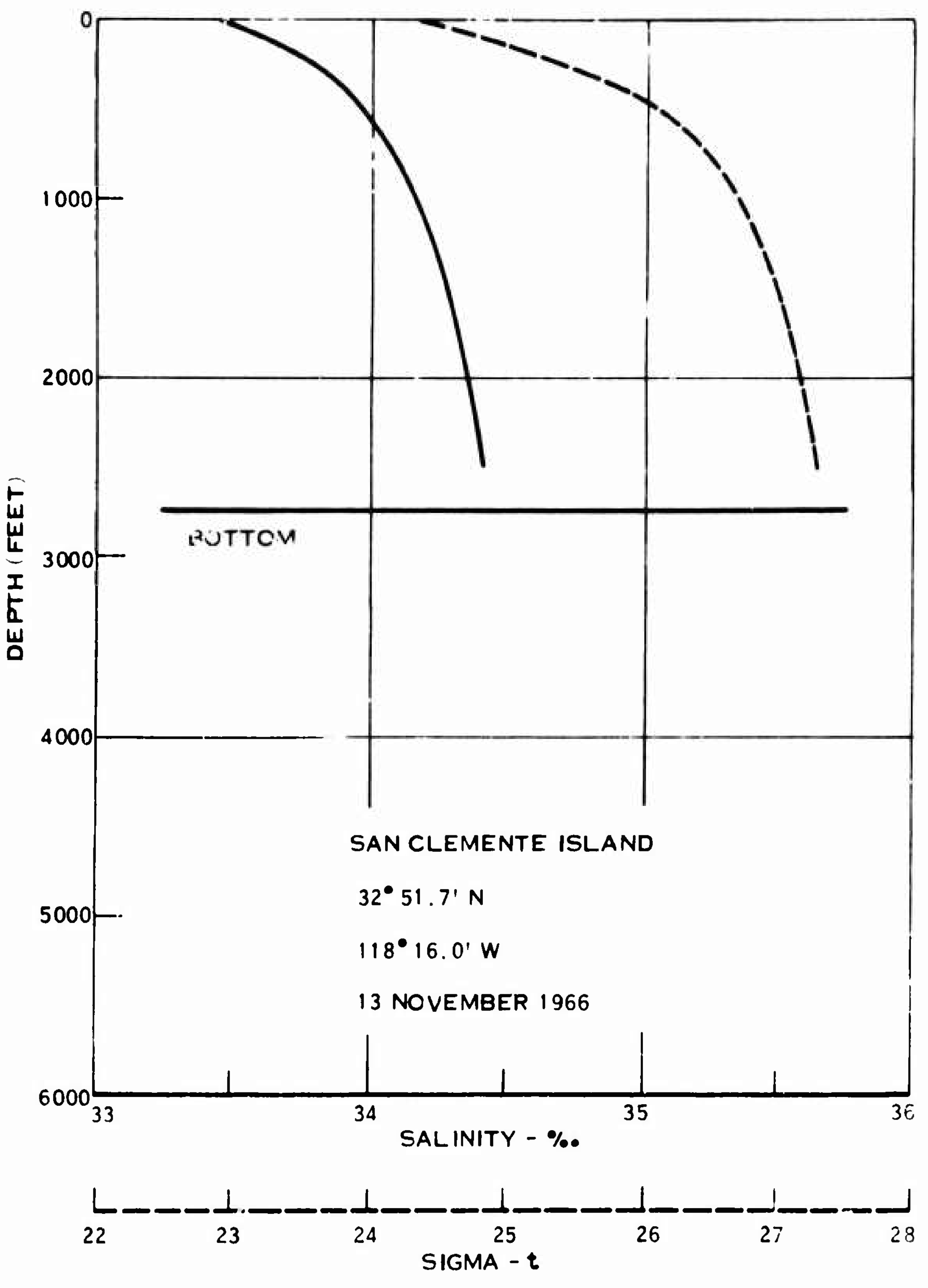

0
1000
2000
3000
4000
5000
6000
DEPTH (FEET)
BOTTOM
SAN CLEMENTE ISLAND
32° 51.7' N
118° 16.0' W
13 NOVEMBER 1966
33
34
35
36
SALINITY - ‰
22
23
24
25
26
27
28
SIGMA - t

Figure 3-5.

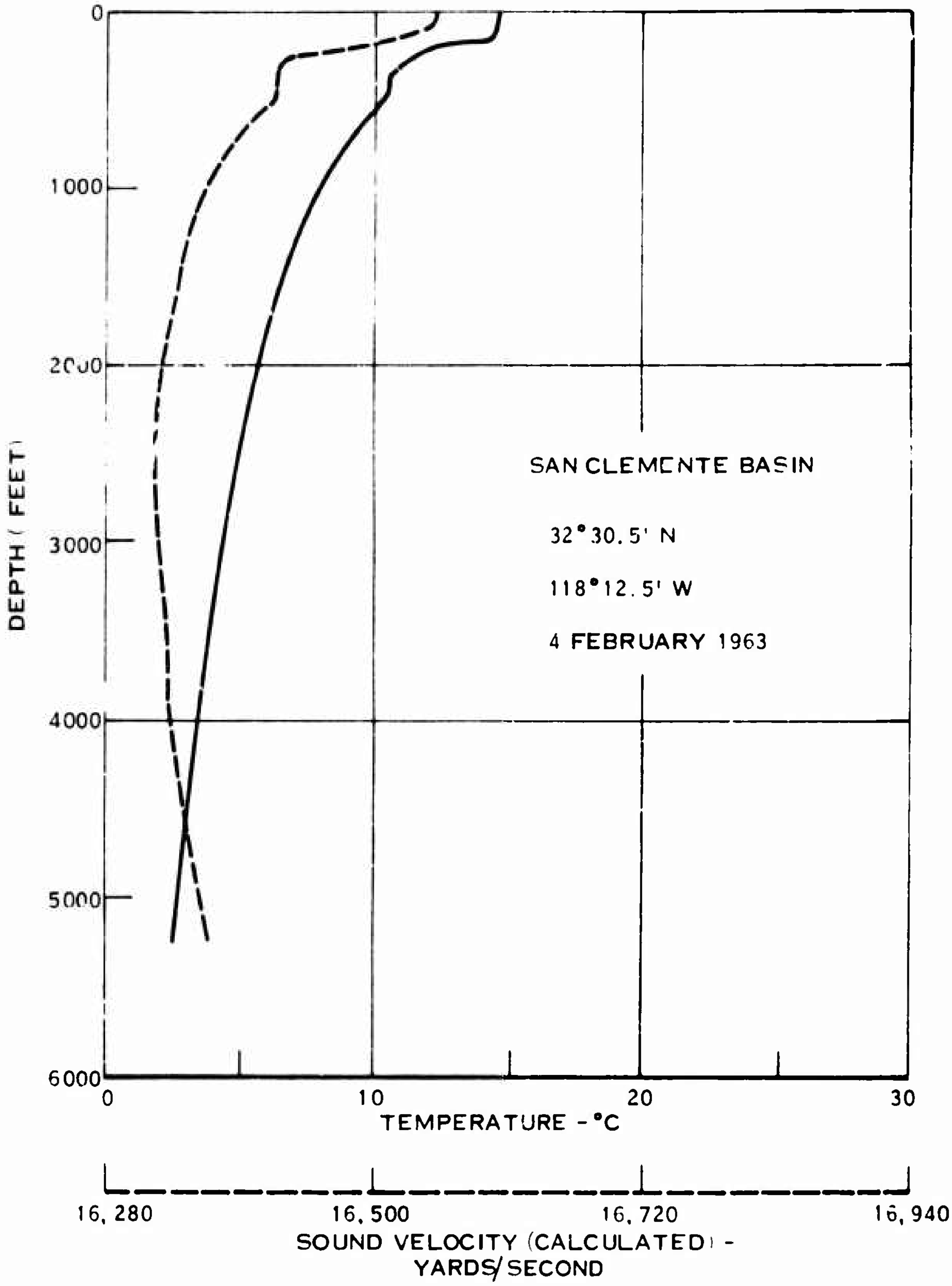

0
1000
2000
3000
4000
5000
6000
DEPTH (FEET)
SAN CLEMENTE BASIN
32°30.5' N
118°12.5' W
4 FEBRUARY 1963
0
10
20
30
TEMPERATURE - °C
16,280
16,500
16,720
16,940
SOUND VELOCITY (CALCULATED) -
YARDS/SECOND

Figure 3-6.

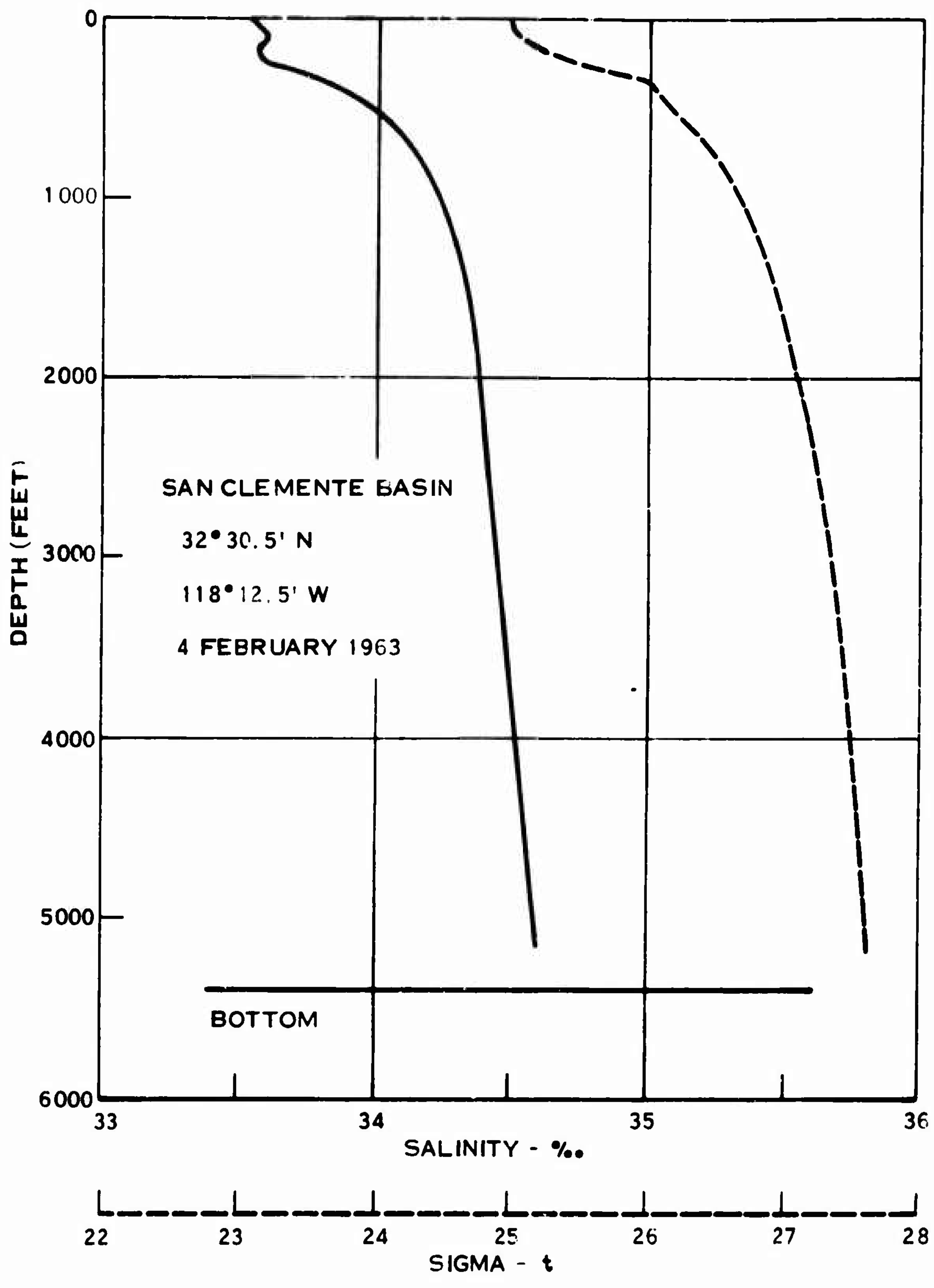

0
1000
2000
3000
4000
5000
6000
DEPTH (FEET)
SAN CLEMENTE BASIN
32° 30.5' N
118° 12.5' W
4 FEBRUARY 1963
BOTTOM
33
34
35
36
SALINITY - ‰
22
23
24
25
26
27
28
SIGMA - t

Figure 3-7.

In all cases, the maximum currents were recorded only once during a five day period. Quality of the data taken near the bottom made interpretation of individual points difficult and there is therefore some doubt that the maximum currents shown in Table 3-1 are accurate. The greatest current speed of significant occurrence frequency was recorded at Station 4 at 500 feet as 1.30 knot. Bottom currents of significant frequency of occurrence reached a maximum of less than 1.0 knot.

There was some correlation between tidal movements and current speed, which indicates that tides exert influence as deep as 6,000 feet. Currents were generally rotary with change of tidal height corresponding to change in current speed.

TABLE 3-1

Station	Position	Water Depth (feet)	Instrument Depth (ft)	Current Speed (max) (kt)	Prevailing Directions
1	33° 3.4'N 118°34.8'W	870	834	0.4	
2	32°58.8'N 118°28.8'N	3750	3737	1.6	
3	32°56.7'N 118°19.8'W	4080	536 2195 4053	1.60 1.1 2.6	SE-NE SE-SW
4	32 °28.4'N 118° 6.4'W	6078	6066	0.5	NNE-SW-W

3.2.9 Visibility

Visibility off the east coast varies such that the most turbid water is generally between 90 and 120 feet deep, with maximum visibility at depths between 450 and 600

feet. Turbidity at shallow depths is probably the result of plankton concentrations. Visibility in any single location varies with time, depending mostly on current effects.

Typical data for areas adjacent to the island are shown in Figures 3-8 and 3-9. Figure 3-10 results from data taken in the San Clemente Basin at 6,066 feet. Under artificial lighting conditions, visibility ranges from 42 to 390 feet.

3.2.10 Bottom Topography

Along the northeast coast of the island, the bottom contours follow the coastline very closely down to 1,500 feet. Beyond. the contours begin to diverge south of the mid-island point. Approximately 8 miles northeast of the island, a prominent near circular subsurface dome disrupts an otherwise nearly flat plane of about 3,600 feet. This dome is approximately 8 miles across the base at 3,600 feet and has a minimum depth of 2,400 feet.

The San Clemente fault scarp which forms the steep northeast slope of the island continues from above sea level to the basin floor. The scarp is rocky and has an average slope of about 16° out to the 3,000 foot contour. Between 2,400 and 3,600 feet, however, the slope is about 7° at mid-island. Maximum depth near the island is about 4,200 feet.

San Clemente Basin, southeast of the island, diverges from San Clemente Canyon. The head of the canyon is located just southwest of Pyramid Head. The basin has a maximum depth of about 6,600 feet. The eastern side of the basin is bordered by Forty Mile Bank which rises to within 260 feet of the surface and serves to block mainland derived sediments. Because of the relative paucity of these sediments, the basin floor is somewhat irregular, but it is likely that a suitable station site could be found since average slope is quite flat.

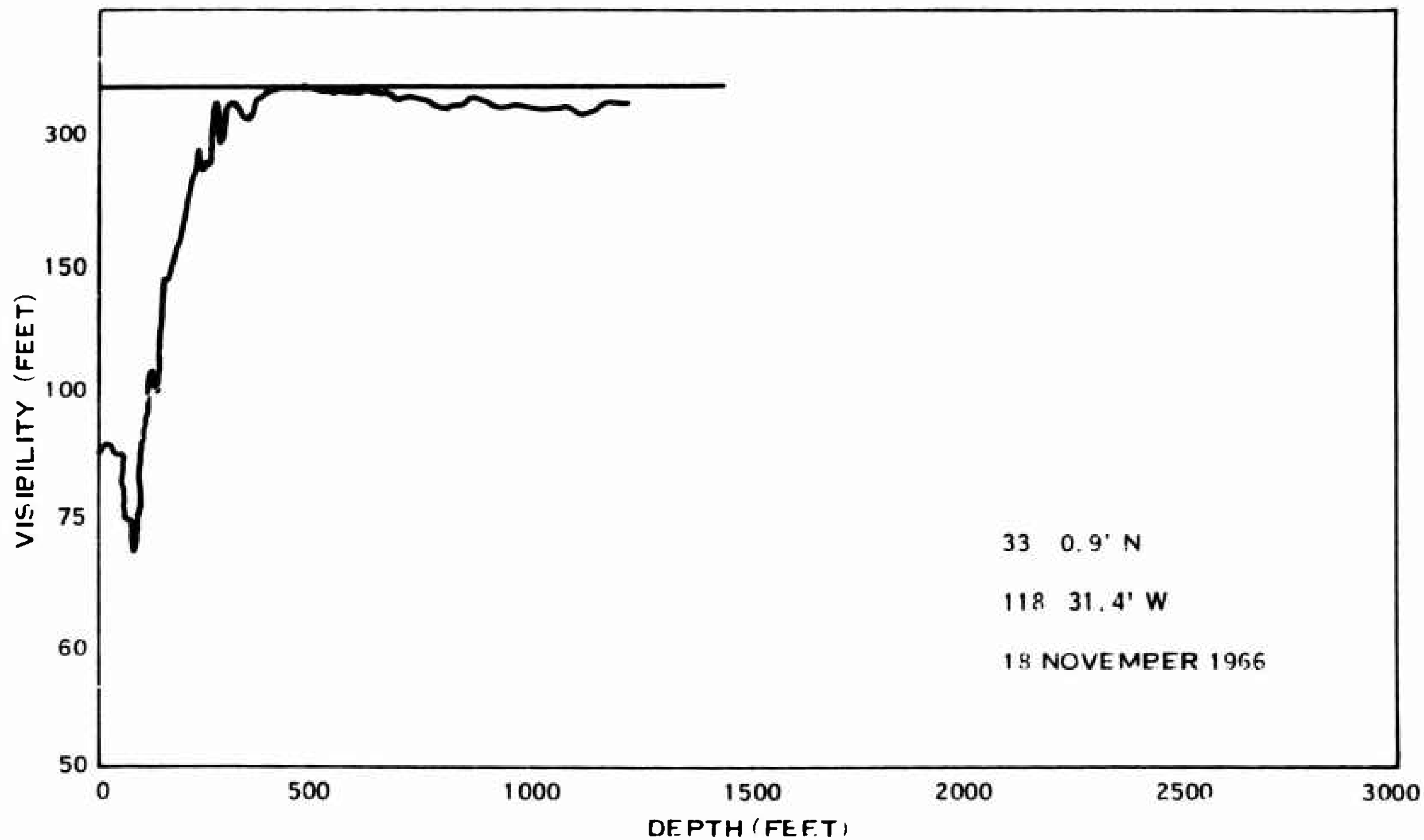


Figure 3-8. Visibility vs. Depth - San Clemente Island

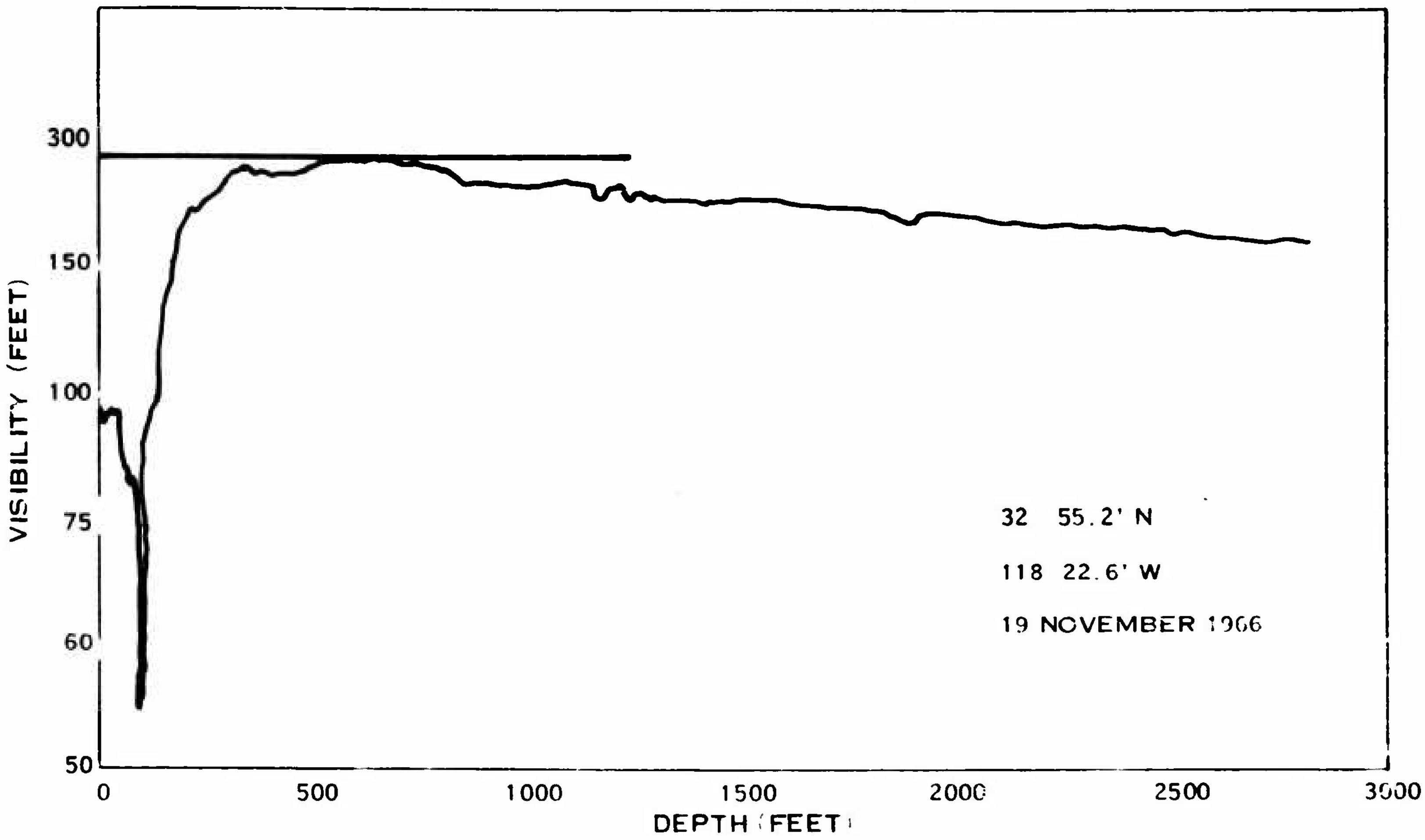


Figure 3-9. Visibility vs. Depth - San Clemente Island

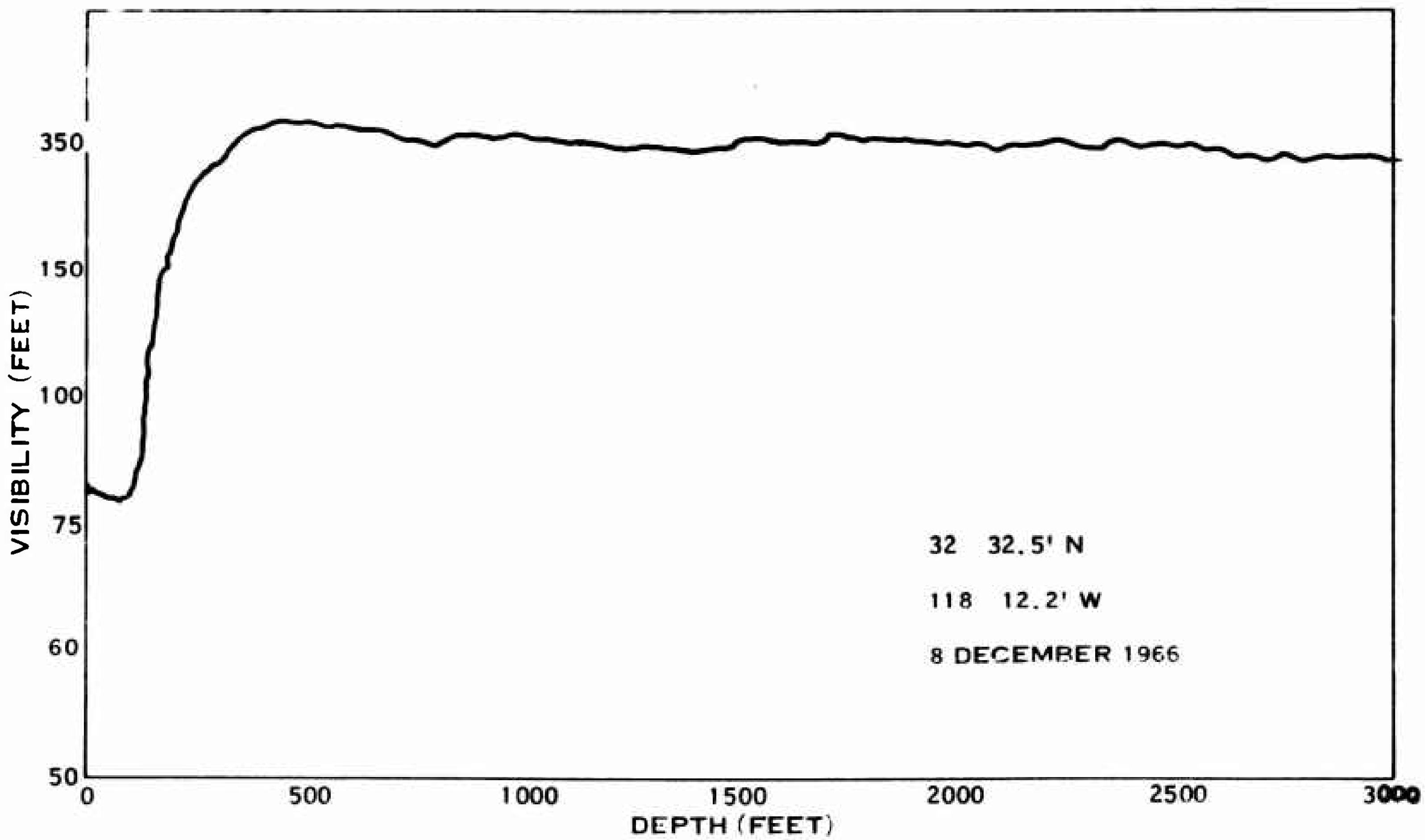


Figure 3-10. Visibility vs. Depth - San Clemente Basin

3.2.11 Bottom Composition

The bottom northeast of the island at 3,000 feet grades from sand to clay. The San Clemente Basin bottom is largely silty-clay. From a number of core samples taken northeast of the island, the bearing strength for the core interval 15-22 cm. range from 5.0 to 38.7 g/cm^2 with average about 7 g/cm^2. Sediment strength increases almost linearly from top to bottom in the cores. Sensitivity (the ratio of natural strength of a sample to the disturbed strength of the same sample) averaged about 2, that is, the remolded sample lost 50% of its original undisturbed strength.

3.2.12 Seismicity

Historically, severe seismic activity in the sea area between San Clemente Island and the coast of California is very low although the fault scarp which forms the northeast coast of the island is considered to be in an active fault zone.

Evidence from submarine topography and from seismicity probes indicate that contindental structures underlie a large submarine area extending northwest off the coasts of both California and Oregon. The present structure is determined by block faulting primarily, although older folder structures exist. The general trend of faults is NW-SE. Volcanic activity is low. The San Andreas Fault is the principal seismic locus of the region.

Some damage to shipping and waterfront areas on the Southern California coast occasionally occurs due to seismic sea waves (tsunami), generated far away (as off the Chilean Coast). Damage in 1960 in the Los Angeles harbor was due to rapid currents which caused mooring lines to part setting floating docks and ships adrift.

3.3 HAWAIIAN ISLANDS - GENERAL

The Hawaiian Archipelago is group of 8 large islands centered at approximately 21°N, 158°W and extending for about 1400 nautical miles in the Pacific. The major islands are mountaneous and of volcanic origin; the island of Hawaii has two volcanoes still active.

The pleasant climate is due to the influence of the ocean and persistent northeast trade winds. Trade winds are dominant in all seasons, reaching maximum intensity and persistency in summer. Where high mountains cut off trade winds on the west sides of the islands, the result is a combination land-sea breeze effect and southwest winds.

Pressure and circulation are the result of the semi-permanent high pressure cell known as the Pacific High, with clockwise circulation around the cell. Thunderstorms are infrequent and never severe. Hurricanes and tornado storms are rare.

All coastal areas are subject to high relative humidity due to the marine climate effect. It is less humid in August and September, more humid in autumn or early winter. Frequent and heavy showers fall almost daily on windward and upland areas, with the heaviest fall at night. More rainfall occurs November-April than from May-October. Local temperature is controlled by elevation and location. August and September are the warmest months and January and February, the coldest. At Honolulu, the average monthly temperature ranges between a low of 72°F in January-February and a high of 78.5°F in August.

Kona (leeward) weather refers to the southerly winds and associated weather on the normally leeward slopes of the principal islands, which, due to wind shift, have temporarily become the windward slopes. Konas occur mostly during October-April and provide the major climatic variation of the islands. Heavy rainfall and cloudiness

accompany the Konas on the lee sides of slopes and coasts. Near gales may occur, especially when wind is funneled through mountain passes.

There are variable oceanic currents in the vicinity of the island of Hawaii, dependent mostly on the direction and velocity of prevailing winds. There are many reports of strong northeast currents setting against the prevailing trades. There is a prevailing westward oceanic drift in the vicinity of the larger islands.

Tidal currents are generally weak and are influenced by winds and oceanic movements. Tidal currents are of the reversing type in the channels between larger islands, but of a rotary nature in open sea areas, shifting direction continuously in clockwise direction.

Periodic tides around Hawaii average 1-2 feet. Effect of strong winds, added to normal tidal action, may cause greater variations.

Rift zones and volcanic vents are active in the islands. On the island of Hawaii there are Kilavea, Mauna Loa and Hualala. The Hawaiian Archipelago is an active volcanic region and most small shocks on the island are direct results of volcanic processes comparatively near the surface. There are, however, some shocks of tectomic origin, resulting in fracturing at the surface due to displacement of large masses of underlying magma or solid material.

The area is frequently visited by seismic sea waves, causing loss of life and severe damage to waterfront property and harbors. Destructive force is usually greater on the side of the island facing oncoming waves, but waves may reach greatest heights on leeward side of islands depending on configuration of island, bottom topography and wave reinforcement.

Despite the volcanic activity on the islands, there is no history of seismic activity in the areas of interest off shore, such as there is, for example, in the vicinity of the Puerto Rican and Japanese trenches.

3.4 HAWAII

The island of Hawaii (Figure 3-11) is triangular in shape, 82 nautical miles north to south and 72 nautical miles east to west. Two of its five volcanoes are still active: Mauna Loa and Kilaueo.

3.4.1 Climatology (Hilo, Hawaii)

Air Temperature (monthly average): January 70, June 74, December 71, March 70, August 75 (°F)

Normal precipitation (inches): January 14, March 15, June 6, September 10, Total annual precipitation 139

Average annual humidity: 81%

Average mean speed of winds 6.3 knots from WSW (can average 12 knots)

No fog

Mean surface water temperature: January 71, March 70, June 72, September 73 (°F)

3.4.2 Weather

Northeast trade winds appear to divide at Cape Kumukahi, one part following the coast northwest and losing its force when it rounds Upolu Pt., the other part following the coast southwest and around KaLae. On the west coast of Hawaii, except at Mahukoma, the sea breeze sets in about 9 a.m. and continues until displaced by the land breeze which starts about sundown. Rainfall varies greatly with locality with the greatest amount falling on the windward side. Storms from the southwest and northwest are most frequent in January and February.

From records of observations made in the area throughout the year for a number of years, the sea state is predominately 3 or lower with rare occurances of sea state 9 and 7 (see Figure 3-12). The higher sea states occurred in November and December respectively.

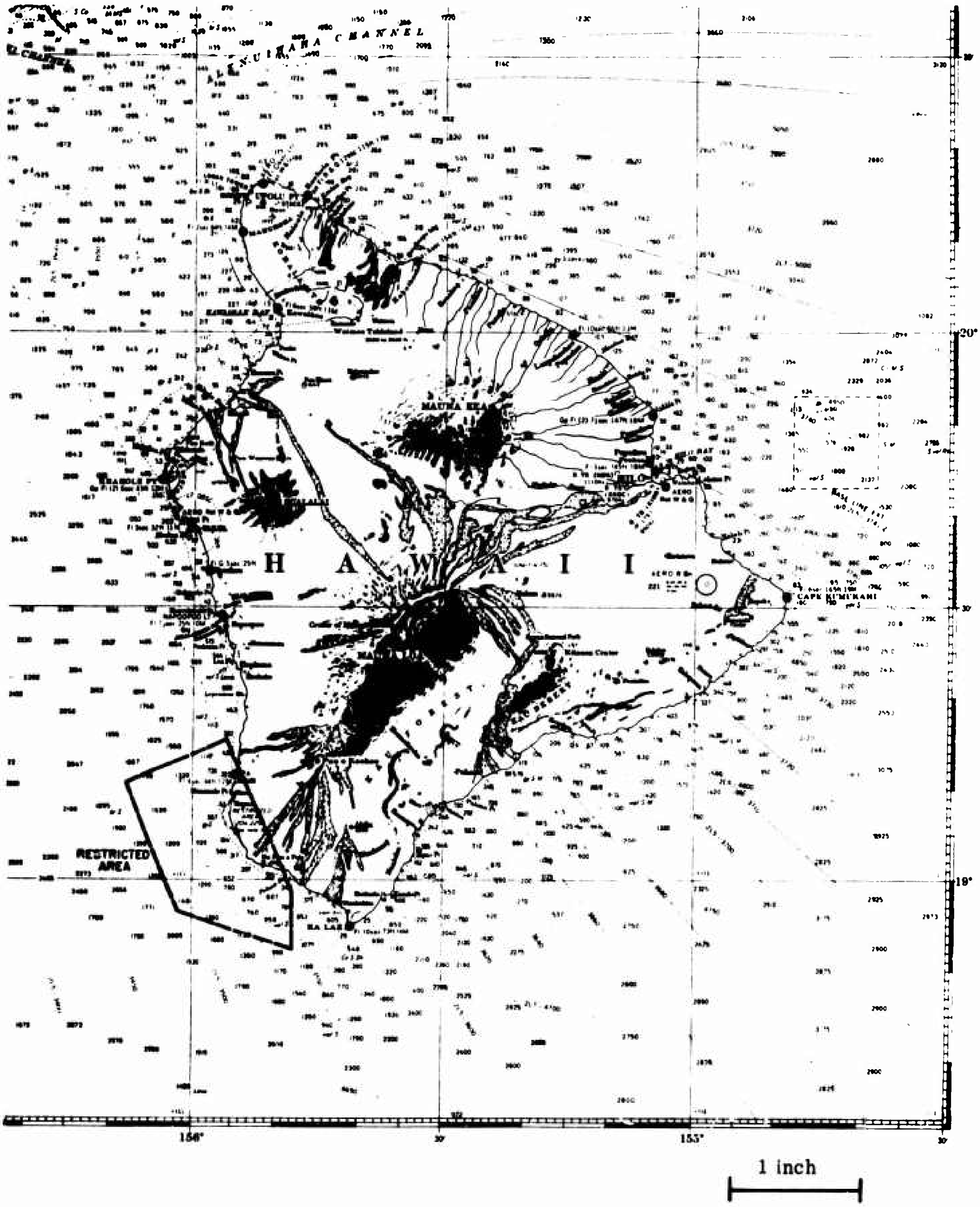


Figure 3-11. Hawaii

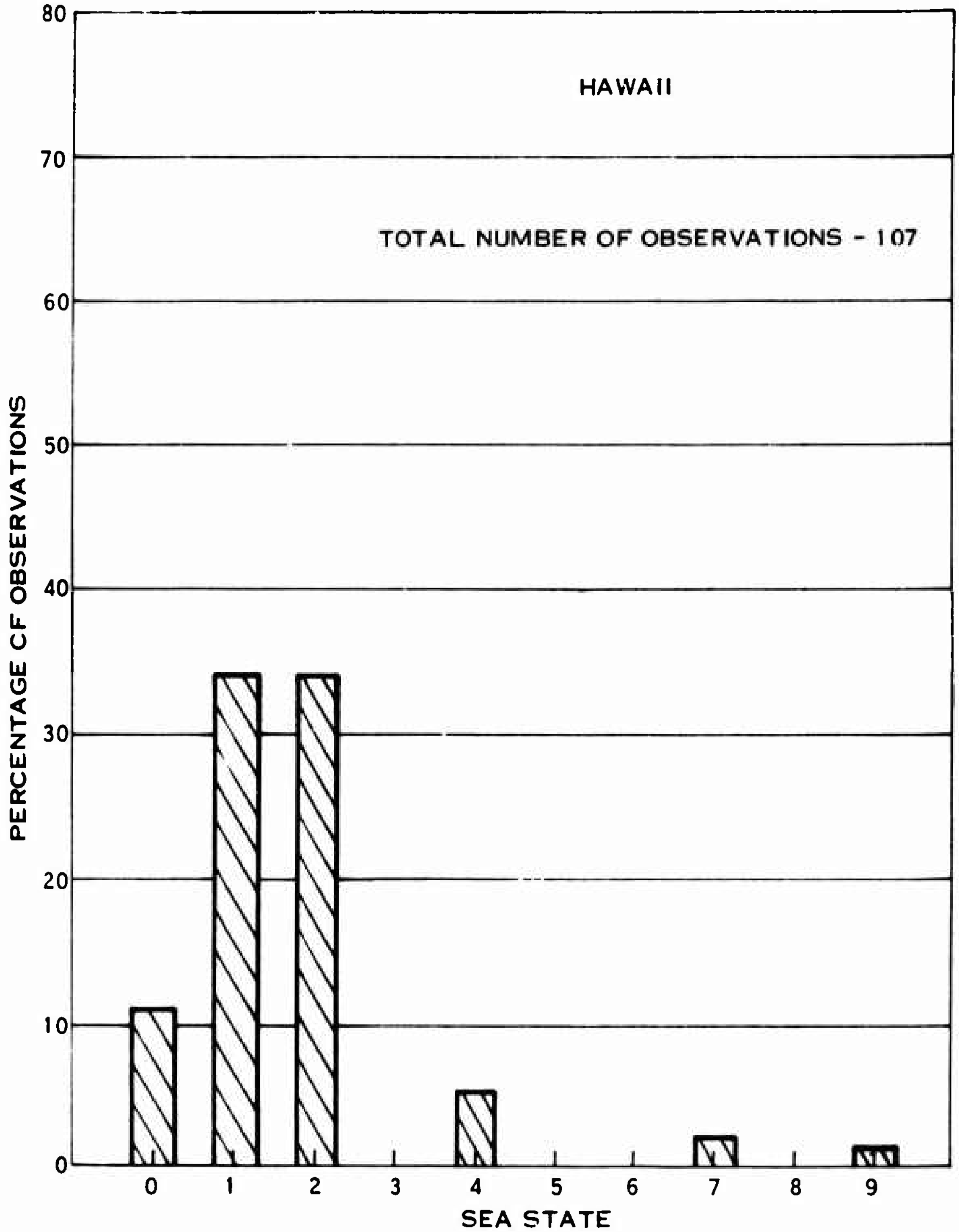


Figure 3-12.

Sea State vs. Percentage of Observations

3.4.3 Coasts and Harbors

Good anchorage is available along much of the west (lee) coast. The northwest coast is bold. The largest reef extends about 0.6 miles from shore in Kawaihae Bay while other reefs off the Capes extend more than 0.3 miles. All reefs can be avoided by staying at least 1 mile offshore.

Kealakekua Bay, 40 miles northwest of KaLae, is the best anchorage along the coast, affording good anchorage in all but strong southwest winds.

Kawaihae is a commercial deep water harbor in the northern part of the bay. Entrance channel depth is 40 feet, main basin is 35 feet. The diurnal range of tide here is 2.1 feet.

No harbors or anchorages along west coast afford shelter during all winds; all are smooth during regular northeast trades but exposed during Kona weather. The trade winds draw around KaLae and hold northward offshore for about 3 miles, generally causing a rough sea. Close inshore, the sea is generally smooth.

3.4.4 Restricted Areas

There is a restricted area (practice aerial target) just south of Hanamalo Point extending seaward past the 6,000 foot contour west of Milohii and effectively covering areas of interest from 7 miles north to 20 miles south of Hanamalo (see Figure 3-11).

3.4.5 Surface Currents

Surface currents generally follow the northeast trade winds and average 0.5 knots or less. One current follows the coast northwest from Cape Kumukahi and around Upolu Point, the northern extremity of the island. Another current follows the coast southwest from Cape Kumukahi around KaLae and thence north to Upolu Point; the latter flow is accompanied by an inshore counter-current which sets southeast from Hanamalo Point around KaLae and thence northeast against the trade winds to Kaeuhou Point.

Offshore, the current sets southwest or south. From KaLae north to Upolu Point, an inshore current sets north from Hanamalo Point and sometimes attains considerable velocity (1/2 kt). There are reports of strong northeast currents off Makolea Point and strong north currents at Mahukona. Currents are weak at Kawaihae. Southwest currents with velocities of 0.5 knots have been observed in Kiholo and Honokaope Bays.

3.4.6 Water Column

Water column data for a point off the southwest coast is plotted in Figures 3-13 and 3-14.

3.4.7 Bottom Topography

Along the western coast of Hawaii from Kauna Point north to Makalea Point, the 6,000 foot contour generally follows the outline of the coast and is 6 miles or less off shore. Between Kauna Point and Keahole Point, the average bottom seaward slope between 600 and 3,000 feet is close to 30°, while the slope between 3,000 and 6,000 feet averages 14° to 18°.

Above Makalea Point to north of Upolu Point, the northern extremity of the island, the bottom slope lessens so that due west of Mahukona the 6,000 foot contour extends to some 40 miles off shore. Here, the average slope decreases to as little as 1°.

Much of the coast between Kailua Bay and Kawaihae Bay is jagged lava extending through the intertidal zone. Cable laying might be difficult in this area.

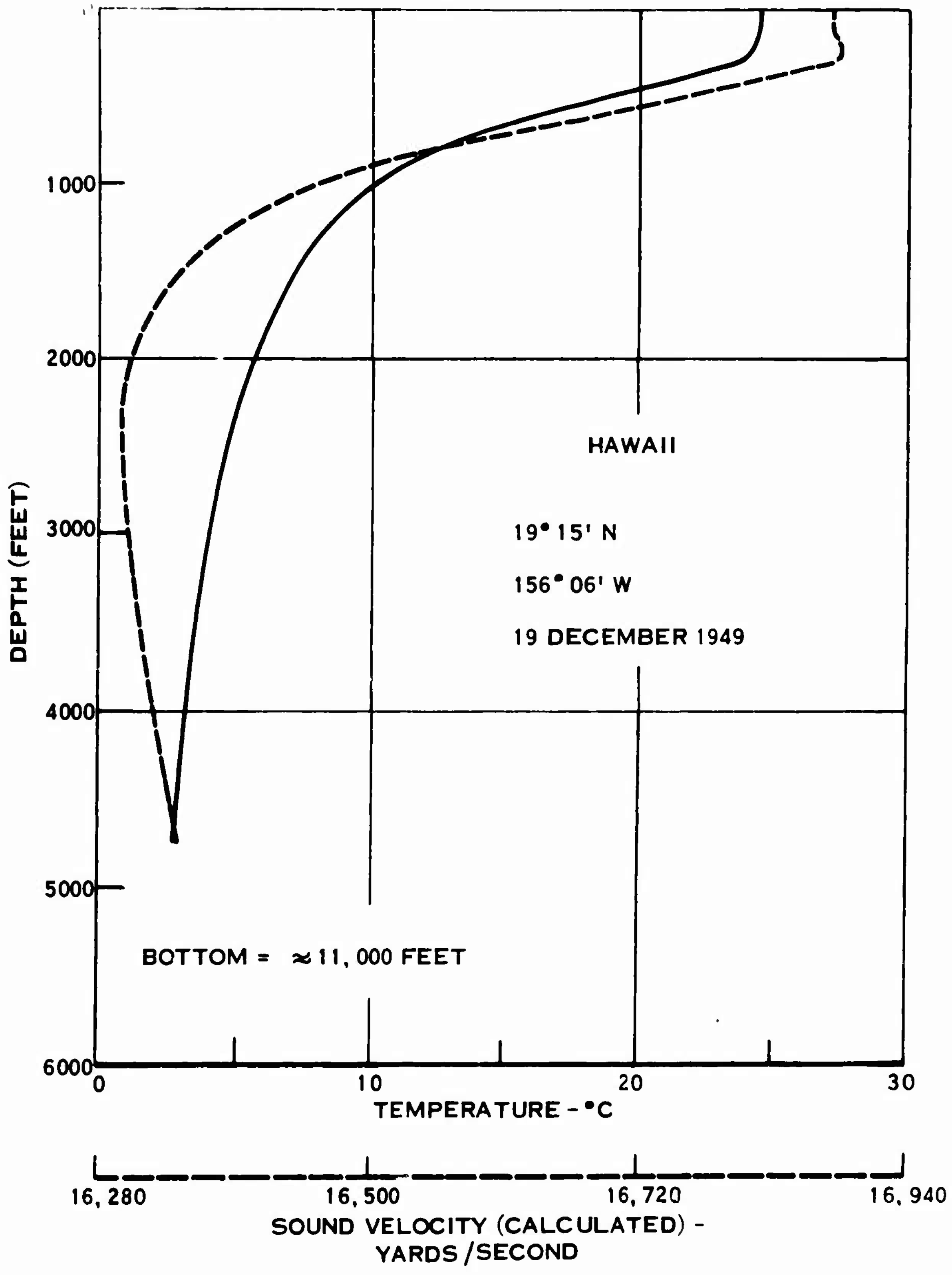
3.4.8 Bottom Sediment Data

a. V20-61 18-54N, 156-27W

Core depth - 14,592 feet

Core taken - 4/14/64

Core length - 486 cm



1000
2000
3000
4000
5000
6000
DEPTH (FEET)
HAWAII
19° 15' N
156° 06' W
19 DECEMBER 1949
BOTTOM = ≈ 11, 000 FEET
0
10
20
30
TEMPERATURE - °C
16, 280
16, 500
16, 720
16, 940
SOUND VELOCITY (CALCULATED) -
YARDS / SECOND

Figure 3-13

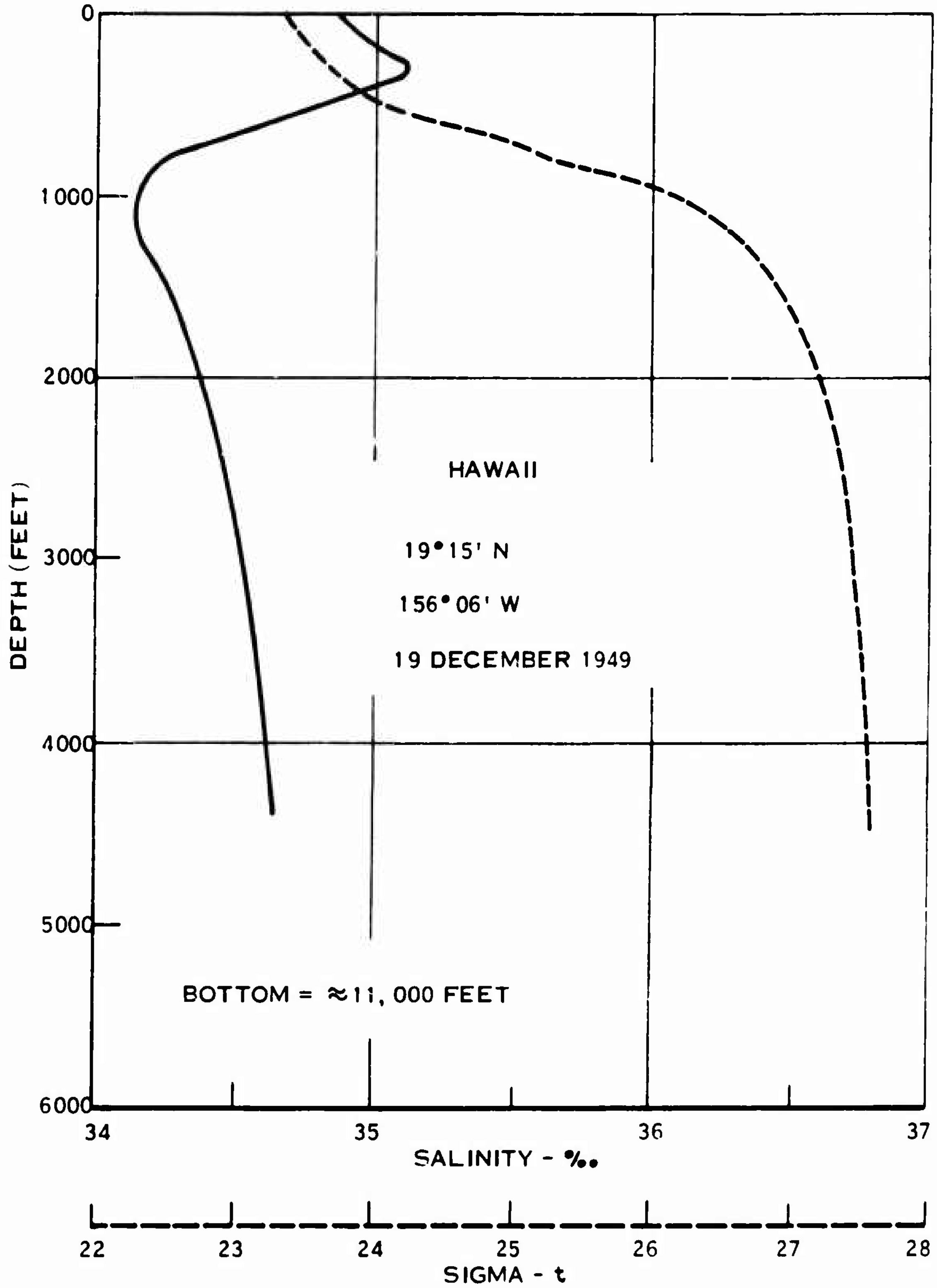

HAWAII
19°15' N
156°06' W
19 DECEMBER 1949
BOTTOM = ≈11, 000 FEET
DEPTH (FEET)
0
1000
2000
3000
4000
5000
6000
34
35
36
37
SALINITY - ‰
22
23
24
25
26
27
28
SIGMA - t

Figure 3-14

Brownish gray and yellowish brown radiolarian ooze overlying sand sand at 363 cm. Some burrowing. Sand layer at 23-26, 40-41, 130-132, 163-166, 170, 268 cm.

b. V20-62 19-09N, 157-20W

Core depth - 14, 688 feet

Core taken - 4/14/64

Core length - 27 cm

0-11 cm mud, dark yellow brown, soft and plastic

11-27 cm diatomatious ooze, soft and moist

c. V20-63 19-09N, 157-20W

Core depth - 14,208 feet

Core taken - 4/15/64

0-230 cm sandy mud, gray-orange color

3.5 KAUAI ISLAND

Located 63 miles across Kauai Channel from Oahu, Kauai Island, measures 29 miles in east-west and 23 miles north-south directions (see Figure 3-15).

3.5.1 Climatology (Lihue)

Monthly average air temperature: January 70, March 70, June 76, September 78 (°F)

Annual precipitation: 42 inches (maximum in October-March)

Average annual humidity: 70%

Annual mean wind: 10.2 knots from northeast

The trade winds divide on the east side of Kauai, part flowing north and part south and again uniting some distance west of the island. On the west side between Mana Point and Makaha Point calm or light, variable winds prevail. The east and north sides (windward) of island have heaviest rainfall reaching a maximum yearly average of 400 inches. The south side averages 20 inches a year. The strongest winds are in winter (December-March) sometimes reach gale force.

3.5.2 Wave Action

The Nohili Point area of the Mana Plain is frequently subjected to large, strong waves generated by winter storms in the Gulf of Alaska and Aleutian Islands areas. Waves of this type can be expected to produce breakers up to 20 feet in height and 14 to 16 seconds apart. It is the violent horizontal accelerations of bottom water associated with the passing of these waves that are most to be feared in the construction and maintenance of engineering structures in the nearshore zone. Waves of this type have been measured approaching from 300° T, having periods of approximately 12 seconds and heights in 40 feet of water of about 12 feet. The surge on the bottom produced by these waves is sufficient to violently throw a diver back and forth 18 to 20 feet along the bottom at velocities of 2 or 3 knots. Bottom conditions throughout the nearshore area indicate strong water movements along the bottom.

Offshore, the average sea state is relatively low as indicated by Figure 3-16. Historically, wave heights are 3 feet or less more than 85% of the time.

3.5.3 Coast and Harbors

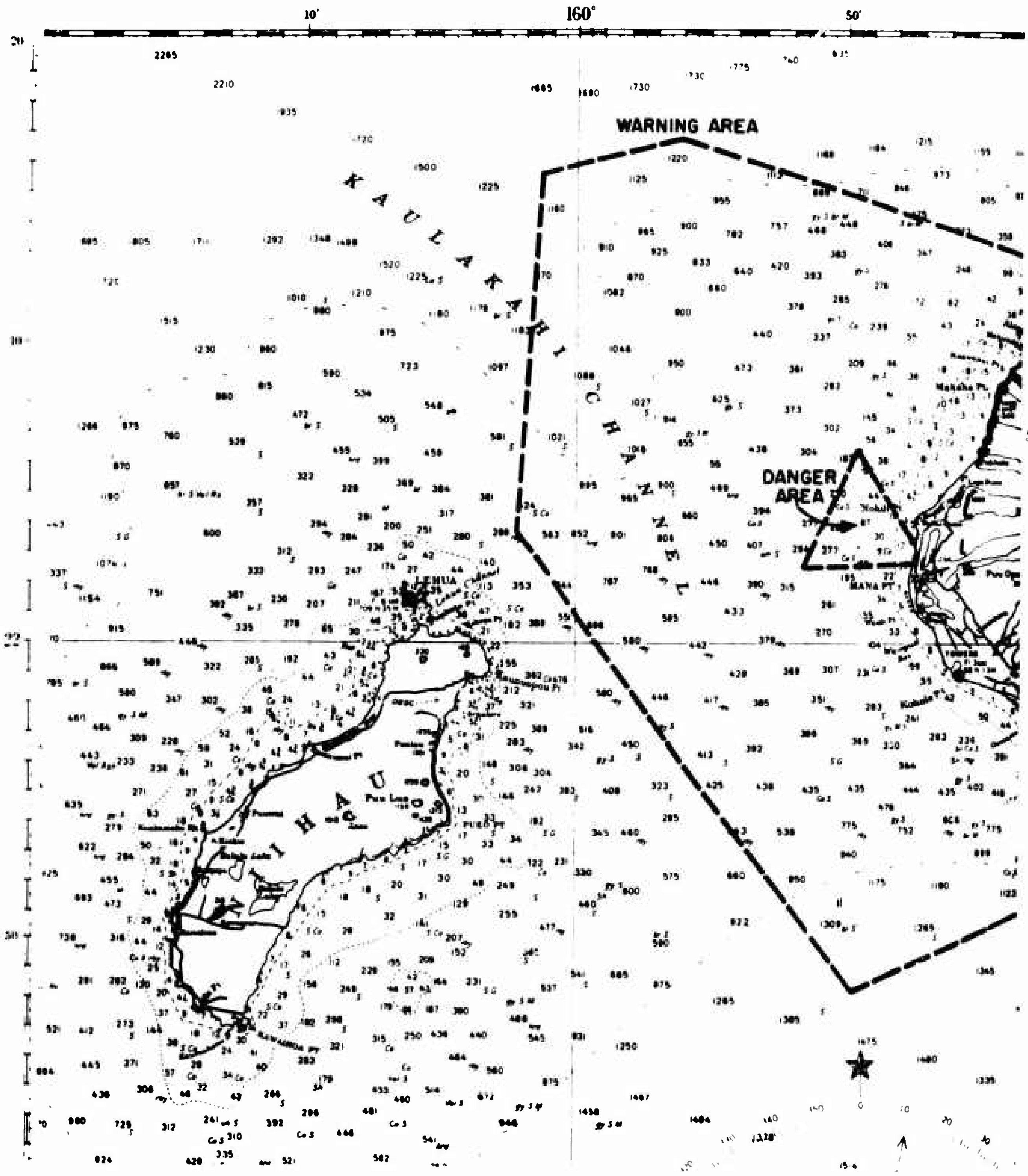
Nohili and Mana Points are located at the western end of Kauai (the center of the lee side of the island). Extending along the coast for 2.5 miles northeast from Nohili Point is a chain of sand dunes known as Barking Sands. A narrow sand shoal with depths of 42 to 60 feet extends from Nohili Point 7.5 miles to Alapii Point. The shoal, appearing to be a succession of east-west sand ridges, lies 1 to 2 miles from shore.

The coastal section between Alapii and Kailiu Points is rocky and precipitous. A series of cliffs are found here reaching 2,000 feet high in some places. They are cut up by numerous streams forming small waterfalls. Kailiu Point is the seaward end of a jagged ridge ending abruptly in a sharp peak 1,200 feet high. There is a narrow strip of lowland at the point.

Mana Point, just south of Nohili Point is the westernmost extremity of the island. Along the water's edge is a strip of sand which extends 2 miles on either side of the point, but the sea breaks on a lava ledge at the edge of the sand making the beaching of boats dangerous except when the sea is smooth. Lava ledges and reefs extend southeast from Mana Point through Kokole Point to Warmea and Hoanuanu Bay. Proceeding eastward to Port Allen, the coast varies from low rocky bluffs to sandy beaches with some reefs interspersed.

Hoanuanu Bay has depths of 12 to 18 feet and affords good protection from trade winds for small craft. The east side of the bay is rocky; the northwest is a sand beach.

Good anchorage can be found in and off Waimea Bay during ordinary weather in depths of 18 to 120 feet, sand bottom. Better protection for small craft in strong trade



1 inch

5. 2 n. m.
(Reduced Scale)

A

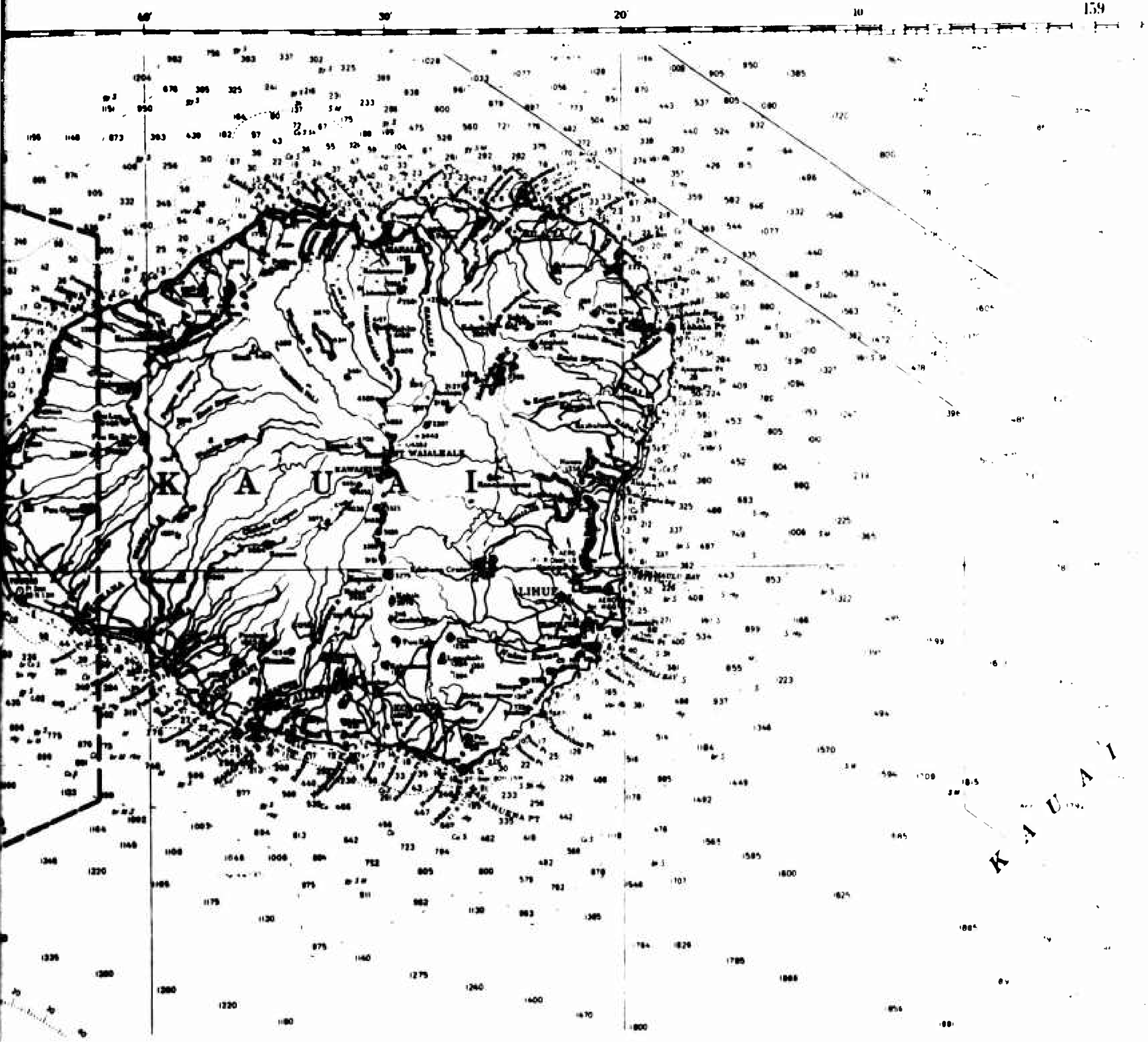


Figure 3-15. Kauai

B

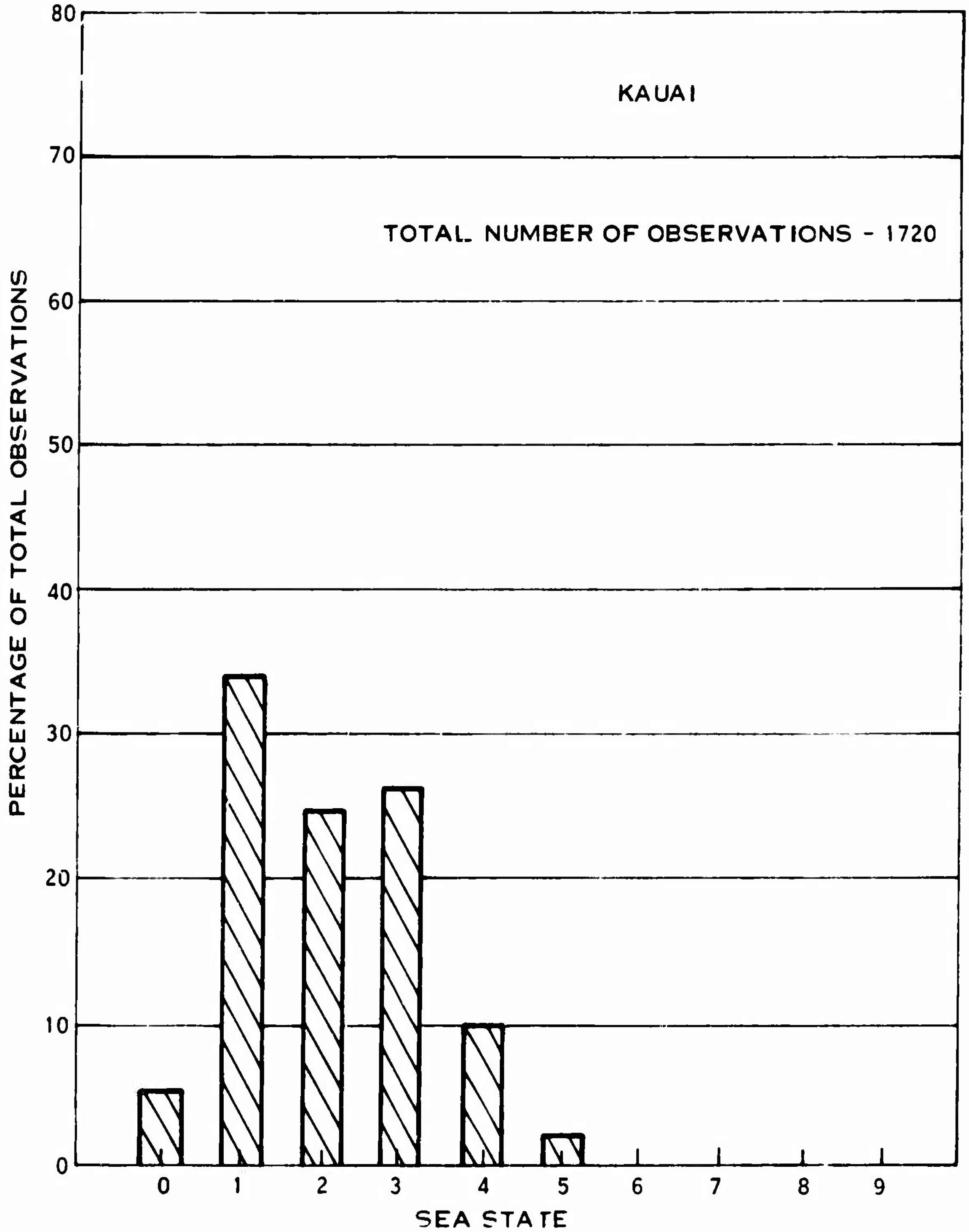


Figure 3-16.

Sea State vs. Percentage of Observations

winds is found at Hoanuanu Bay. Depths of 5 to 18 feet extend 0.3 miles from the shore of Waimea Bay.

The shores at Port Allen are low, rocky bluffs with a sandy beach at the head of the bay. A reef extends 600 feet from the shore eastward. In heavy weather breakers extend 1,000 feet offshore on the northwest side of the bay and 150 to 450 feet off the southeast side of the point. Pilotage is necessary and a small tug is available for towage. The usual anchorage off Port Allen is in 54 feet, coral and sand bottom, about 0.5 miles southeast of the breakwater light. The harbor affords shelter for all craft in all weather, but may become congested. There is a small craft harbor north of the pier. The duirual range of tide is 1.7 feet.

3.5.4 Restricted Areas

A missile test range extends out into the ocean (Kaulakahi Channel) from the western end of Kauai Island. The warning area begins in the north nearby Dapii Point and fans out westward toward Niihau Island. The warning area extends southward through Kaulakahi Channel and bounds on the coast of Kauai about 1/2 mile northwest of Waimea Bay. A smaller triangular danger area extends westward from an apex located between Mana Point and Nohili Point (see Figure 3-15).

3.5.5 Surface Currents

Oceanic currents in the vicinity of Kauai generally follow the winds. Tidal currents off Mana Point average 0.8 knots setting north and south.

Little is known of the current in Kaulakahi Channel (between Kauai and Niihau), but presumably it is variable depending mainly upon the velocity and direction of the wind. There appears to be a general northwestward flow along the southwest coast of Kauai.

The general offshore current is a movement of water from east to west, which is related to the North Equatorial Current System. This offshore current is consistent, but of small magnitude; i.e., in the range of 1/2 to 1 knot.

Important to the emplacement of power cables are the strong, somewhat erratic currents within the surf zone. Under conditions of large advancing waves, nearshore currents of three knots have been measured off Nohili Point. A strong rip current of several knots is fed by an alongshore current moving inside the surf zone southward at about 3 knots.

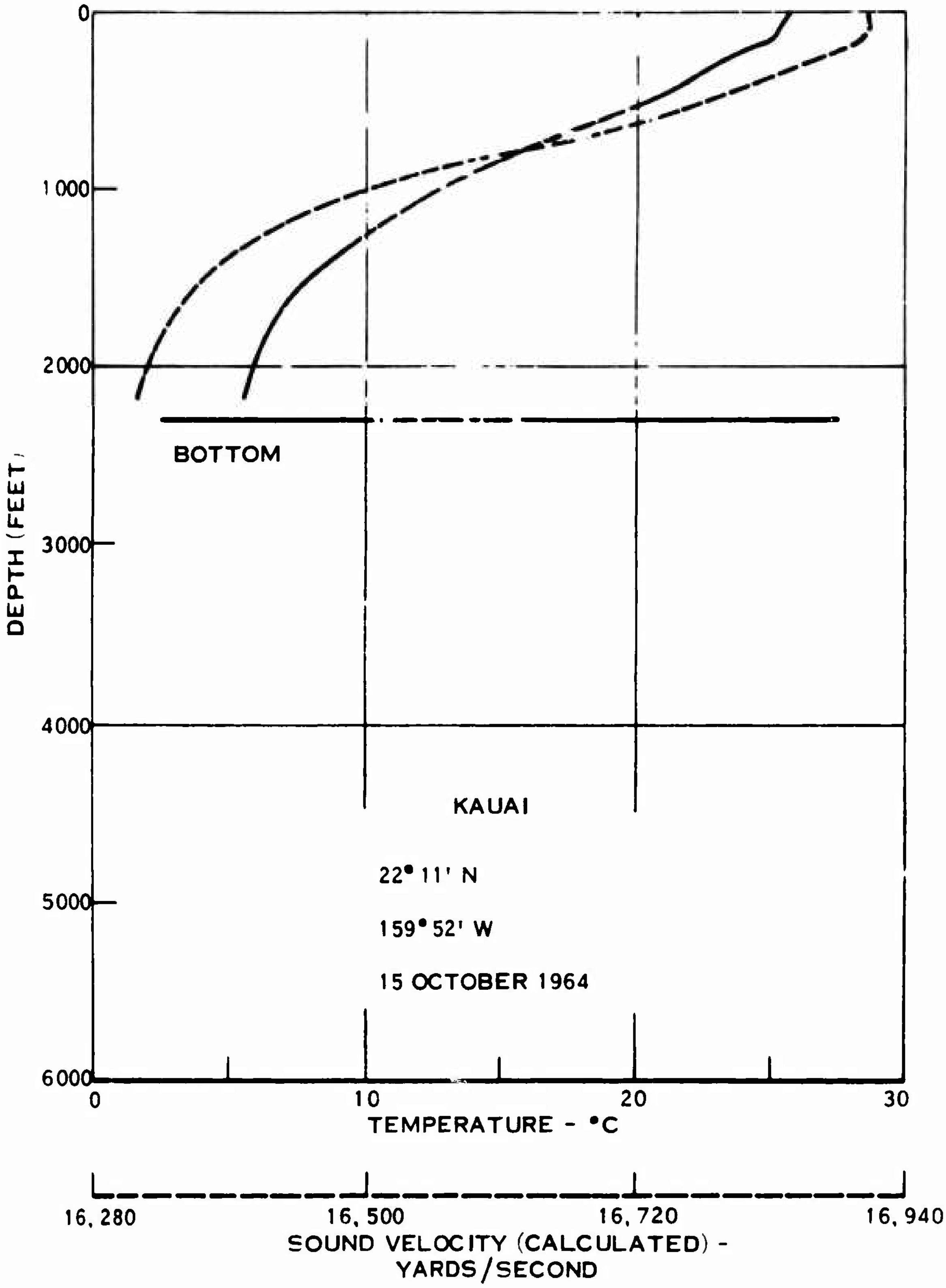
3.5.6 Water Column

Temperature, sound velocity, density and salinity profiles for an area midway down the island are shown in Figures 3-17 and 3-18.

3.5.7 Bottom Topography

The offshore bottom topography at Nohili Point consists of two major classes: (1) a nearshore zone of flat, hard beachrock surfaces and escarpments, and (2) an offshore zone of massive calcareous reef material channeled, scoured, and undercut by wave action and partially covered by thin patches and strips of calcareous sand. The interface between these two major bottom types occurs approximately 230 feet seaward and 15 feet below MLLW.

The thick outcrops of hard beachrock present nearshore extend from about 230 feet offshore in 15 feet of water through the surf zone and under the beach and would be very difficult to trench for power cables. It is only on the very upper portions of the beach that the sand thickness is sufficient to allow trenching without encountering this beachrock. Beachrock ledges are numerous and escarpments between the ledges are pronounced.



DEPTH (FEET)
0
1000
2000
3000
4000
5000
6000
BOTTOM
KAUAI
22° 11' N
159° 52' W
15 OCTOBER 1964
0
10
20
30
TEMPERATURE - °C
16, 280
16, 500
16, 720
16, 940
SOUND VELOCITY (CALCULATED) - YARDS/SECOND

Figure 3-17.

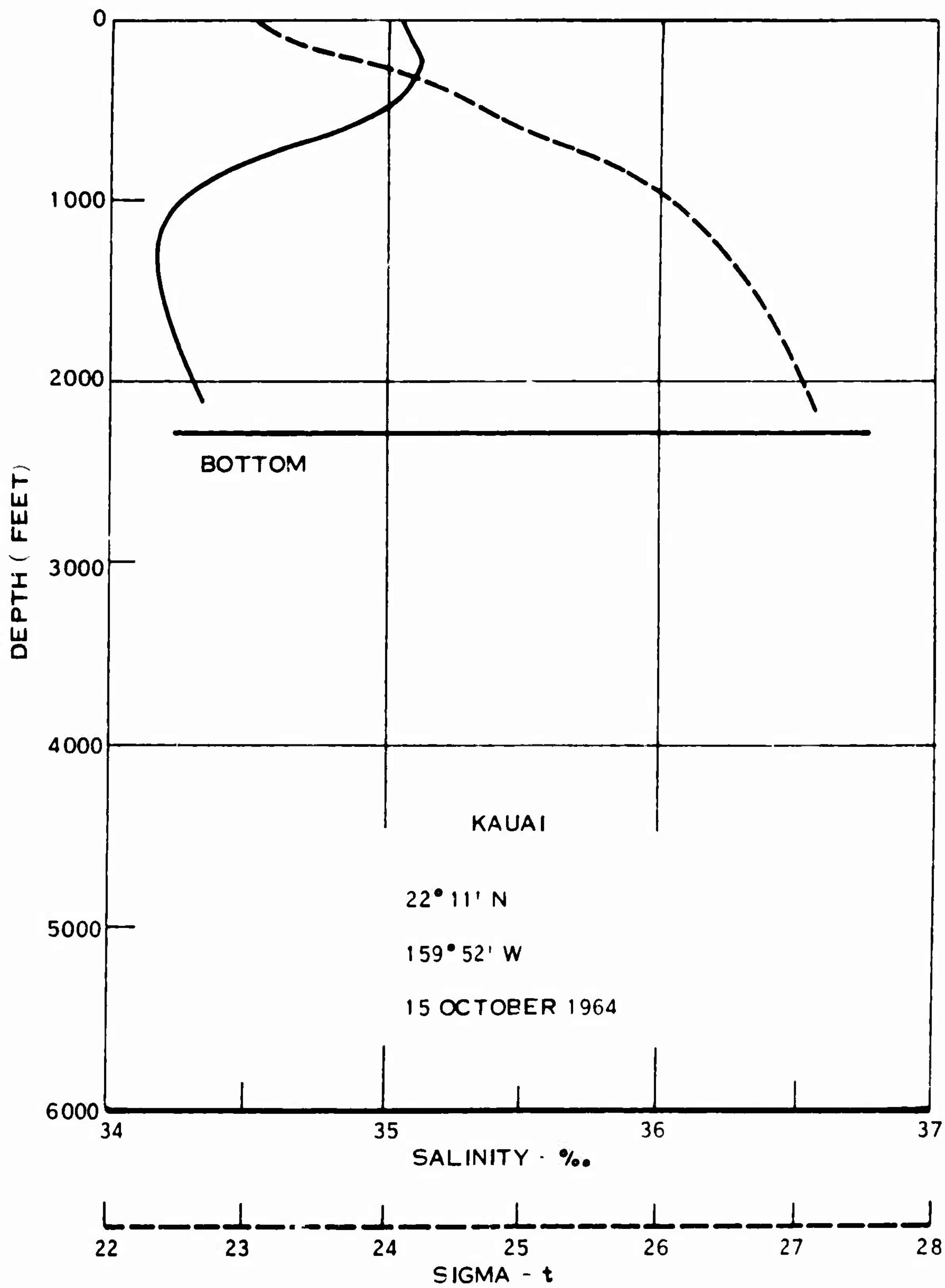

0
1000
2000
3000
4000
5000
6000
DEPTH (FEET)
BOTTOM
KAUAI
22° 11' N
159° 52' W
15 OCTOBER 1964
34
35
36
37
SALINITY - ‰
22
23
24
25
26
27
28
SIGMA - t

Figure 3-18.

The outer portions of both ranges from about 15 feet of water have a substratum of porous reef limestone. Numerous channels, ledges, and elongate depressions, all trending onshore - offshore, would allow easy emplacement of cables in a semi-protected environment even though the offshore area is generally one of high-bottom energies.

3.5.8 Bottom Sediment Data

a. V21-185 23-01N, 159-21W

Core depth - 15,498 feet

Core taken - 9/29/65

Core length - 99 cm

Brown mud turning sandy at 65 cm and finally grading to sand.

b. V21-161 21-36N, 161-26W

Core depth - 14,640 feet

Core taken - 5/8/65

Core length - 593 cm

Red brown, firm mud with sand (much of it volcanic material)

c. V21-60 20-15N, 158-09W

Core depth - 12,036 feet

Core taken - 5/7/65

3.6 SITE SELECTION

On the basis of the results of the environmental studies and other considerations described below, the area west of Hawaii is recommended for a manned underwater station site.

Almost the entire lee side of Kauai is restricted to missile test ranges and the area north of the island is exposed to higher sea states (on the average) than San Clemente Island or the lee side of Hawaii experience (see Figures 3-3, 3-12 and 3-16).

San Clemente Island is convenient to Port Hueneme and should be considered for early check-out development in shallow water, depending on the location chosen for Station construction. Possible interference from shore bombardment and other test range activities, as well as the presence of a fault zone, make the island unattractive for long term station installation. The area is frequently visited by commercial and party fishing boats which often trespass into the restricted areas off the northeast coast. It is unlikely that these fishermen would honor the restrictions of a station site area any more than those of the test ranges.

The San Clemente Basin area, where 6,000 foot depths are attainable, is less protected than the northeast island coast. It is somewhat remote for cable power supply and is adjacent to heavily traveled sea lanes. Moreover, the Mexican border, if extended west from land, bisects the Basin, and some international repercussions might arise if the station were placed south of the extended boundary.

The waters west of the coast of Hawaii offer several advantages. A wide range of depths and bottom slopes would permit placement of the station either close to land to facilitate cable power supply or further out when a reactor is available. The area is sheltered in all but unusual weather. Fishing and shipping are not known to

be heavy up and down the coast. The proximity of Pearl Harbor with its attendant shipyard facilities assures maintenance and repair support and available basing for resupply vessels. With the number of small harbors and population centers along the Hawaiian west coast, it is likely that cable power could be taken directly from transmission lines. In this way construction of a generating plant might be avoided.

Final site selection must be preceded by detailed surveys of bottom characteristics and shore facilities in areas of interest.

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United States Coast Pilot 7 (Ninth Edition)

U. S. Navy Oceanographic Data Center

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4.0 SUPPLEMENTARY VEHICLES

The Deep Submergence Rescue Vehicle (DSRV) is considered to be the prime candidate resupply vehicle. There are, however, reasons for considering additional vehicles.

The DSRV is designed primarily to rescue crew members of fleet submarines disabled beneath the sea surface, and it is unlikely that the priority of this mission will be compromised. The Manned Underwater Station resupply operation, having at best second priority, should not be dependent solely on a vehicle which may well have other Navy commitments at the very time resupply is required.

During early deployment phases, the Station will no doubt be placed at depths less than 3,000 feet for periods of less than 30 days. Unless the DSRV is uncommitted during this phase, an alternate resupply vehicle with lesser depth capability and payload capacity is preferred for ease and flexibility of vehicle support.

As Station utilization is expanded, it may be desirable to rotate the crew at more frequent intervals. Special equipment may be needed which was not anticipated prior to the last resupply mission. Data packages, or special samples may require transport to surface facilities. Replacement of single crew members, for medical or other reasons, may be necessary. These functions could be performed by vehicles smaller than DSRV at less expense in terms of money and operational capability.

4.1 VEHICLE SELECTION

In order to choose alternative vehicles for consideration in an orderly fashion, a survey was conducted to determine which submersibles might be appropriate. Requirements were arbitrarily established for maneuverability, depth capability, and payload capacity. Maneuverability requirements and the lack of a bottom hatch pre-

clude the use of the bathyscaph such as Trieste, modified fleet submarines like Grouper or even the special vessel Dolphin. Depth and payload requirements eliminate a number of the smaller early submersibles. Table 4-1 is a condensation of results of the survey.

As seen in Table 4-1, only seven vehicles have bottom hatches which might allow mating to the Station access chamber or be modified to do so. None of the submersibles, operational or planned, have accommodations for mating a top vehicle hatch to a bottom hatch on an access chamber located at the bottom of the Station. As discussed in Section 2, such a mating is feasible only when the Station is tethered above the bottom at a height which will provide sufficient clearance between the ocean bottom and the lower extremity of the observation sphere. Should a tethered-off-bottom mating eventually prove practical, a number of submersibles might be modified to effect a mating with the observation sphere. For example, a new titanium hull for the AUTEC vehicle is now being designed. Accommodations for observation sphere mating could be incorporated. Since this vehicle will have a detachable hull, the remainder of the vehicle would be relatively unaffected. Assuming that power requirements for mating trunk dewatering would exceed vehicle capability, the dewatering system would have to be provided by the Station.

The prospects of such a mating are attractive from an operational view point since it would afford an alternate access to the Station and would increase the number of feasible support vehicles. However, present stages of vehicle design, lack of standardization in submersible configuration, and absence of experience in Station operation prohibit extensive development of this scheme within the scope of this study.

4.2 MISSION COMPATIBILITY

Any number of mission profiles might be developed for the support vehicle.

Table 4-1

VEHICLE	OPERATING DEPTH (FEET)	PAYLOAD (LBS)	HATCH LOCATION	STATUS	HULL FEATURES
ALUMINAUT	15,000	6000	TOP	OPERATIONAL	ALUMINUM CYLINDER 8 FT. DIAMETER WITH HEMISPHERICAL END CAPS. WELDING ON HULL NOT ALLOWED.
ALVIN	6000	1200	TOP	OPERATIONAL	SINGLE 7 FT. SPHERE, NAVY CERTIFIED.
ALVIN 2	6600	1200	TOP	UNDER CONSTRUCTION	SINGLE 7 FT. SPHERE DETACHABLE FROM SUPERSTRUCTURE IN EMERGENCY.
AUTEC	660	1200	TOP	UNDER CONSTRUCTION	SINGLE 7 FT. DETACHABLE SPHERE.
BEAVER 4	2000	2000	TOP/ BOTTOM	UNDER CONSTRUCTION	TWO SPHERES WITH CONNECTING TRUNK. DIVER LOCKOUT. MATING SKIRT ON BOTTOM HATCH.
DEEP QUEST	8000	7000	TOP/ BOTTOM	OPERATIONAL	TWO 7 FT. INTERSECTING SPHERES WITH BOTTOM HATCH ON AFT SPHERE. PROVISIONS FOR DIVER LOCKOUT CHAMBER AND MATING SKIRT, ALTHOUGH THESE FEATURES ARE NOT NOW INSTALLED.
DEEP DIVER	1500	1500	TOP/ BOTTOM	OPERATIONAL	TWO-CHAMBER CYLINDER WITH DIVER LOCKOUT.
DEEPSTAR 2000	2000		TOP	UNDER CONSTRUCTION	SINGLE 5 FOOT CYLINDER.
DEEPSTAR 4000	4000	450	TOP	OPERATIONAL	SINGLE 6.5 FT. SPHERE, NAVY CERTIFIED.
DEEPSTAR 20,000	20,000	1000	TOP/ BOTTOM	DESIGN	SINGLE 7 FT. SPHERE. PROVISIONS FOR ADDING MATING SKIRT TO BOTTOM HATCH.
DOWB	6600	1000	TOP	OPERATIONAL	SINGLE 7 FT. SPHERE, 360 DEGREE OPTICAL SYSTEM.

					WITH BOTTOM HATCH ON AFT SPHERE. PROVISIONS FOR DIVER LOCKOUT CHAMBER AND MATING SKIRT, ALTHOUGH THESE FEATURES ARE NOT NOW INSTALLED.
DEEP DIVER	1500	1500	TOP/ BOTTOM	OPERATIONAL	TWO-CHAMBER CYLINDER WITH DIVER LOCKOUT.
DEEPSTAR 2000	2000		TOP	UNDER CONSTRUCTION	SINGLE 5 FOOT CYLINDER.
DEEPSTAR 4000	4000	450	TOP	OPERATIONAL	SINGLE 6.5 FT. SPHERE, NAVY CERTIFIED.
DEEPSTAR 20,000	20,000	1000	TOP/ BOTTOM	DESIGN	SINGLE 7 FT. SPHERE. PROVISIONS FOR ADDING MATING SKIRT TO BOTTOM HATCH.
DOWB	6600	1000	TOP	OPERATIONAL	SINGLE 7 FT. SPHERE, 360 DEGREE OPTICAL SYSTEM.
DSSV	20,000		TOP/ BOTTOM	DESIGN COMPETITION	PROBABLY SINGLE 9 FT. SPHERE.
NAIIA	1200	1000	TOP	OPERATIONAL	CYLINDER. SINGLE CHAMBER.
NR-1	3000	UN-KNOWN	TOP	UNDER CONSTRUCTION	10 FT. DIAMETER CYLINDER, NUCLEAR POWER.
PISCES	6000	500	TOP	OPERATIONAL	SINGLE SPHERE, APPROX. 6 FT. DIAMETER.
PX-15	2000	5000	TOP	OPERATIONAL	CYLINDER, APPROX. 8 FT. DIAMETER. HABITABILITY PRIME CONSIDERATION.
GSV-1	2000	5000	TOP/ BOTTOM	DESIGN	SECOND GENERATION PX-15, WILL HAVE LOCKOUT CHAMBER, BUT LESS MANEUVERABILITY.
STAR 2	1200	500	TOP	OPERATIONAL	SINGLE 5 FT. SPHERE.
STAR 3	2000	1500	TOP	OPERATIONAL	SINGLE 5-1 2 FT. SPHERE.
SHELF DIVER	800		TOP/ BOTTOM	OPERATIONAL	TWO-CHAMBER CYLINDER WITH LOCKOUT CAPABILITY.

B

However, for simplicity five arbitrary profiles are described below to typify operating conditions.

Mission A is hypothesized as an early deployment checkout mission, with less than 30 day resupply requirements. The 500 lb. payload might be two men, special equipment or resupply for a short time period.

Mission B might also be performed during early deployment, but with some experience in station operation gained, a longer mission time, more closely approaching maximum capability is desired. This would be a 30 day mission, resupply in four (or fewer) dives.

Missions C and D are operational missions at rated depths with resupply performed in three dives (at most) every 30 days.

Mission E is similar to Mission A, but to 6,000 feet.

Table 4-2 summarizes mission parameters.

TABLE 4-2.
MISSION PARAMETERS

Mission	Maximum Depth (feet)	Minimum Payload Dive
A	600	500
B	1,200	1,500
C	3,000	2,000
D	6,000	2,000
E	6,000	500

The seven candidate vehicles with bottom hatches are categorized as to mission capability in Table 4-3. In addition to DSRV, only Deep Quest and DSSV have total mission spectrum compatibility with respect to payload and depth. Beaver 4 will have dry mating and skirt dewatering capability, but within a limited depth range. Deepstar 20,000 will have full depth range and dry mating capability, but small payload capacity.

TABLE 4-3.

MISSION CAPABILITY

Vehicle	A	B	C	D	E	Mating Capability
Beaver 4	X	X				Dry
Deep Diver	X	X				Wet-diver lockout
Deep Quest	X	X	X	X	X	Wet-diver lockout
Deepstar 20,000	X				X	Dry
GSV-1	X	X				Wet-diver lockout
Shelf Diver	X					Wet-diver lockout
DSSV	X	X	X	X	X	Undefined
DSRV 1	X	X	X			Dry
DSRV II-IV	X	X	X	X	X	Dry

4.3 SUBMERSIBLE CHARACTERISTICS

In addition to depth capability and payload capacity, some consideration must be given to other facets of submersible design. Submersibles have, as a rule, been designed for minimum weight and maximum performance - features which necessitate economical use of available space. Therefore, most of these vehicles have little volumetric capacity for payload other than normal crew and operating equipment.

Gross payload capacity (most often expressed in pounds) may have little relationship to dry payload capacity. The figure given often refers to liftable payload.

Most submersibles to date have only a single pressure hull suitable for human occupancy or dry payload transport. For safety, the ideal resupply vehicle should have lockin-lockout features that allow mating to a chamber in the vehicle other than that containing the vehicle controls. Should the vehicle/station seal fail during resupply, there is a high probability that the vehicle and crew would be lost if no such isolation exists.

Maneuverability is a prime requirement for any submersible under consideration as an alternate resupply vehicle. A good part of the cost of DSRV has been related to the control system necessary to effect mating with minimum risk to vehicle and submarine. Since no vehicle is now operational which has been specifically designed to mate at depth and transfer men and materials in a short sleeve atmosphere, it is impossible to generalize just what the minimum control requirements are. Each vehicle must be investigated in detail to determine its applicability.

Vehicles which have not originally been designed for mating and dry transfer require considerable structural redesign to modify them for this capability. Note that most of the vehicles with bottom hatches are designed for diver lockout only, not dry mating. Depending on the depths involved, pressure hulls may have to be strengthened, fairing superstructure reworked and appendages (mating skirt, transfer trunk) which affect performance and stability added. Vehicles which carry Navy personnel must be certified as safe by the Navy Ship Systems Command. Certification requirements are quite stringent and once a vehicle has been certified, the cognizant organization is understandably reluctant to make modifications which jeopardize this status. Modifications which affect the pressure hull (such as welding, which disturbs existing stress concentrations) are generally avoided once the vehicle is operational.

Tables 4-1 and 4-3 show that no vehicle now planned has the attributes which are requisite for a complete replacement for DSRV under the operating conditions described. This suggests that vehicles should be selected for the particular mission rather than depending upon only one vehicle with overall capability. For example, Beaver 4 might be utilized for small cargo loads for Station installations at depths of 2,000 feet or less. Since a mating skirt, dewatering system and 25-inch diameter hatches are planned for this vehicle, the IES as designed for DSRV will be adaptable depending on the vehicle's maneuvering capability.

4.4 COST EFFECTIVENESS

The cost effectiveness of utilizing a spectrum of vehicles, fitting the vehicle to the mission, is apparent when operating costs are compared. For Deepstar 4,000 operating costs are less than $2,000,000 per year. Estimates for operating DSSV range over $3,000,000 per year. The DSSV will utilize the ASR-21 as a support ship, as will the DSRV, and since support ship costs are by far the major expense with large vehicles, it is not unreasonable to assume similar costs for DSRV.

Since operating costs are mainly dependent on support requirements, it appears that a smaller vehicle making more dives might be most economical, if and when a suitable vehicle becomes available.

5.0 ALTERNATE RESUPPLY METHODS

The use of free-swimming manned submersible vehicles for Station resupply has many advantages. However, should expense or mission priority problems preclude use of a DSRV or similar vehicle, other less sophisticated means for Station support are feasible.

5.1 McCANN RESCUE CHAMBER

For depths to about 600 feet, a submarine (McCann) rescue chamber might be utilized for Station resupply. These chambers have been in Navy use for over 30 years and could provide limited or emergency support on relatively short notice.

5.1.1 Classification

Submarine rescue chambers are assigned to submarine rescue vessels (ASR) as part of their equipment. From 1932 to 1943 rescue chambers were classified as district craft with the identification symbol YRC followed by a serial number. This classification and the use of the symbol YRC has been discontinued. Rescue chambers are identified by serial number, beginning with Serial No. 1 for the rescue chamber formerly designated as YRC-1.

The rated operating depth and test depth are shown below for each design. Chambers of the same design are grouped together. Each group represents a slightly different design.

Rescue Chamber Serial Number		Rated Depth Feet	Test Depth (No Personnel Aboard) Feet
(a)	1 to 5	300	400
(b)	1A, 6, 7	400	600
(c)	8 to 19	550	750

5.1.2 Design

The submarine rescue chamber is a steel structure about 11 feet high having a weight of approximately 18,000 pounds and a maximum outside diameter near the top of 94 inches (nos. 1 to 7 and 1A) or 84 inches (nos. 8 to 19) tapering to a diameter of 60 inches at the bottom. It is open at the bottom and around the bottom edge is a rubber gasket. The chamber has three divisions; the upper compartment, the lower compartment, and the ballast tank. The general configuration is portrayed in Figure 5-1.

On the outside and top of the chamber are watertight fittings for air supply, venting from the interior, the telephone wire, and the electric light cable. The connections go directly into the upper compartment. Air is supplied from the tending vessel. Air is vented through a hose which also runs to the surface vessel.

A hatch with a raised coaming about it permits entrance from the top to the upper compartment which contains all the operating gear except the reel for the downhaul wire. It is the compartment in which the operators and passengers ride.

The air-supply line terminates at a blow and vent manifold. At this manifold is the lower compartment blow valve and the ballast tank blow valve, which when opened admit air to the top of their respective compartments. On the blow lines from the valves to the lower compartment and to the ballast tank are the lower compartment and ballast tank vent valves. Both the lower compartment and the ballast tank vent into the upper compartment and the air from there escapes to the surface through the upper compartment vent valve. Three additional ballast tank vents are provided for rescue chambers Nos. 1A and 6 to 19. These vents are located at intervals around the chamber and consist of a short length of 1-inch pipe leading from the top of the ballast tank to a valve in the upper compartment.

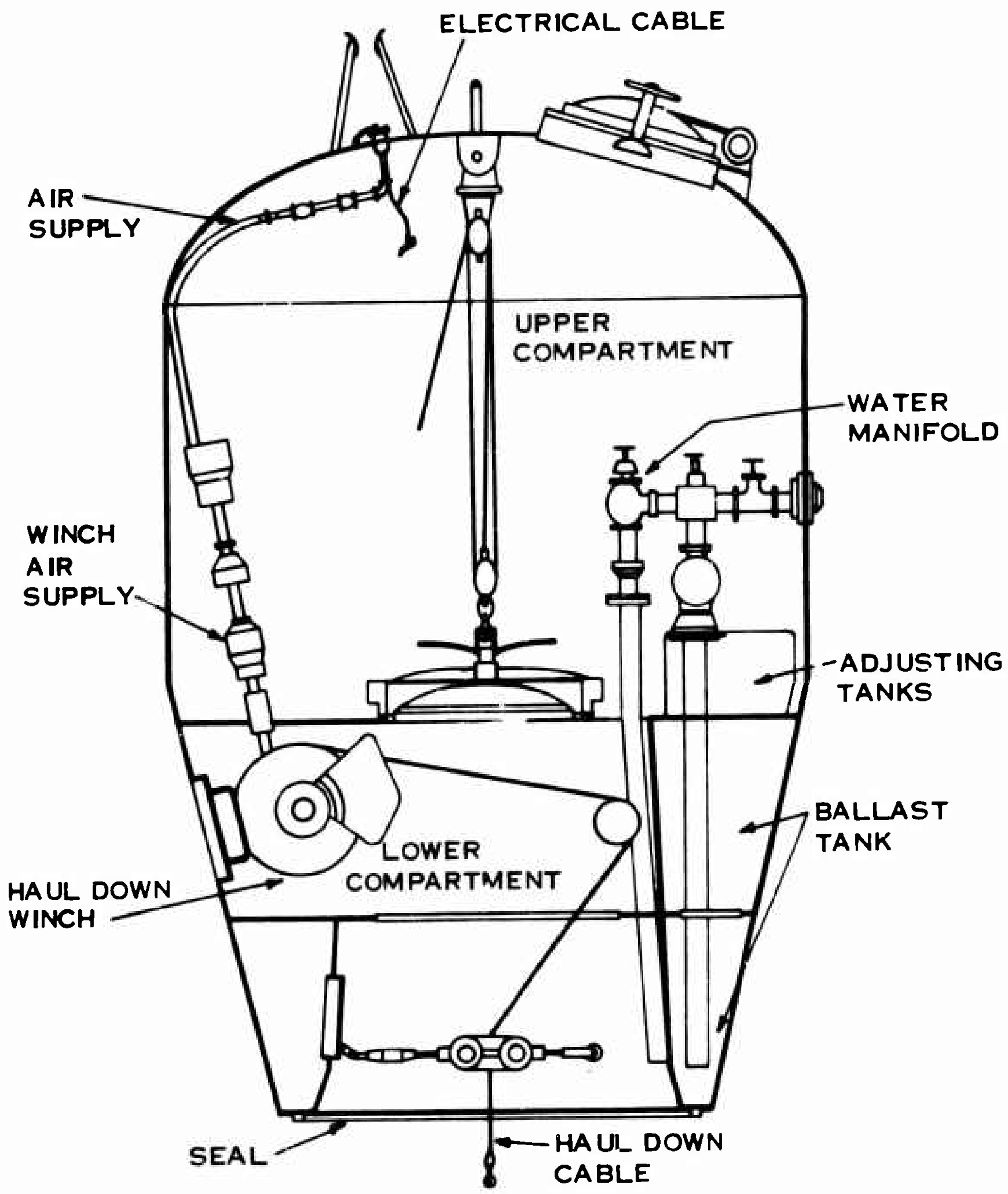


Figure 5-1.

McCann Rescue Chamber

Adjacent to the blow and vent manifold is the water manifold. This consists of the sea valve, the lower compartment flood valve, the ballast tank flood valve, and the valve for the hose connection. With the sea valve open, sea water flows through an opening in the hull and through a line to the two flood valves and hose valve. From the flood valve, flood lines run to the bottom of their respective compartments. On both the air and water manifolds the inboard valves go to the lower compartment and the outboard ones to the ballast tank.

In addition to the water manifold, rescue chambers Nos. 1A and 6 to 19 are fitted with three 1-inch spill pipes which connect the ballast tank to the sea. Each of these pipes is provided with a valve located in the upper compartment. The spill pipes terminate near the bottom of the ballast tank and are spaced at intervals around the tank. If the chamber is in an inclined position with the water manifold on the high side, use of the spill pipes instead of the water manifold permit more complete blowing of the ballast tank.

Portable galvanized tanks are arranged in a circle around the inside of the upper compartment. They are readily accessible and are used to compensate for the gain or loss in weight of the chamber with the entrance or departure of passengers. The number and capacity of the tanks vary for the different rescue chamber designs. The total capacity is approximately 1,000 pounds of water.

The lower compartment, which is open at the bottom is connected to the upper compartment by a hatch. It contains the downhaul cable and reel, a snatch-block through which the wire runs, and a fairlead for the wire which centers it in the compartment when hauling in or veering. One end of the downhaul cable is secured to the reel and a special shackle is made fast to the other end to fit the hatch bale on the submarine hatch. The fairlead can be moved out of the way after the cable has been unfastened from the submarine hatch.

The blowing, venting, and flooding connections in the lower compartment are all controlled from the upper compartment. In a circular web running around the inside of the hull in the lower compartment are a number of slots spaced at equal intervals. The hold down rods, stowed in the upper compartment, fit into these slots and the nuts are screwed tight against the web. The shackle on the bottom of the rod is secured to a pad eye outside the submarine hatch, and with four rods in use, the chamber is held tightly to the hull of the submarine.

When the water is sufficiently deep, and the submarine is on an even keel, with no relative positive pressure within it, the use of hold down rods may be dispensed with, as the seal caused by sea pressure will be sufficiently strong to hold the chamber tight against the hatch.

Rescue chambers Nos. 1A and 6 to 19 are provided with a cable cutter for emergency use. This device is permanently mounted in the lower compartment in way of the downhaul cable and is operated from the upper compartment by means of a small hydraulic hand pump.

The lower compartment has a capacity of about 3,000 pounds of salt water.

The ballast tank is a closed annular compartment in the hull of the rescue chamber and surrounds the lower compartment. The capacity of the ballast tank is almost the same as that of the lower compartment. In the bottom of the tank is placed lead ballast for regulating the weight of the chamber.

The rescue chamber has just enough ballast in the form of lead inside the ballast tank so that it will have a positive buoyancy of 1,000 pounds with the lower compartment full of water, the ballast tank dry, the adjusting tanks full of water, and two operators in the upper compartment.

5.1.3 Operation

The rescue chamber is transported to the scene of operations by towing. Its great weight and the danger of rough handling in a seaway render the carrying of it aboard the rescue vessel inconvenient and at times dangerous. The gasket on the bottom is especially liable to injury in handling the chamber on a ship.

For towing, the chamber is placed in the water with all loose articles well secured, all valves and hatches closed, and the ballast tank dry. A towing wire is run from the stern of the vessel to the lifting pendant of the chamber and towing is done astern. Towing may be done at any speed the wire can stand. At speeds of more than 5 knots the chamber will not tow upright but the only effect of this will be to flood the lower compartment partly. The chamber cannot sink under these conditions if it is properly ballasted, the ballast tank is dry, and there are no leaks.

Upon arrival over the sunken submarine, the rescue vessel lays out a mooring with the center as nearly as possible over the submarine. The rescue vessel then hauls herself to such a position that the submarine lies to leeward about 50 to 100 feet. The chamber is brought to the leeside of the rescue vessel and all connections are made.

While this work is going on, the diver is preparing for his descent. After arriving on the submarine's deck, he first clears away any material which may block the approach to the hatch, and makes sure that nothing lies on or in the vicinity of the seat surrounding the hatch. The shackle end of the rescue chamber downhaul cable is then made fast to the bale on the submarine hatch. The diver is then brought to the surface and stands by for a descent if his services are needed by the crew of the rescue chamber.

The chamber is now ready for the descent. Two operators are sent inside and the upper hatch is closed.

As the chamber descends, the hose, telephone wire, and light cable are bound together for convenience in handling and paid out. The wire attached to the lifting pendant is also paid out. There is never a strain on this wire and it is necessary only to pull the chamber over to the rescue vessel after the ascent.

The sea pressure will seal the chamber tight against the seat after ballast adjustments have been made. Sealing is assisted by taking in any slack in the cable as it comes. The operators may determine if the seal is made by looking through the eyeport into the lower compartment. If the seal is made, the lower compartment will fill with vapor. If the compartment fills with water instead of vapor, the attempt has been unsuccessful and it will be necessary to secure, blow the lower compartment, and try again. Repeated failures indicate an obstruction on the seat which must be removed, either by the diver or, if the operators are experienced, by the chamber crew itself.

A total of six average-sized men may be taken aboard the chamber without reducing the reserve buoyancy below 1,000 pounds by emptying all the adjusting tanks in the upper compartment.

The passengers who are to make the trip go to the upper compartment with one member of the chamber crew. The operator in the lower compartment then closes and screws tight the submarine hatch, replaces the fairlead and shackles the downhaul wire to the hatch bale. The other operator then takes in all slack on the wire. When the downhaul wire is taut, the operator in the lower compartment removes the hold down rods and passes them up into the upper compartment. Then he also enters the upper compartment.

The ballast tanks are then blown, the seal broken and the chamber's buoyancy lifts it to the surface. Ascent speed is regulated by keeping tension on the hauldown cable.

On the surface the passengers exit through the upper compartment hatch and the sequence is repeated until all crew members are removed from the submarine.

5.1.4 Station Support

While the McCann chamber is relatively crude by today's standards, it is an existing method of dry transferring 1200-1500 pounds of men and materials to a depth of 600 feet. The bottom gasket diameter is within one inch of that of the DSRV mating skirt gasket, so the Station vehicle mating platform could be utilized. Since Navy personnel have been trained in chamber use with an ASR, operations in support of a Manned Underwater Station would simply be an extension of present capability.

Unless a permanently buoyed cable is suspended to the Station from a point near the surface, a diver or small submersible with manipulator must connect the downhaul cable to the Station hatch prior to the first dive. This could be avoided by adding a second winch, with nylon line and a float, to the Station for deployment to the chamber on the surface.

Aside from the depth limitation the major disadvantage to dependence on a McCann chamber for Station support is its payload capacity. Since 5 dives would be necessary for 30 day resupply, replenishment would be a lengthy process; probably in excess of 12 hours. However, for small loads or emergency personnel transfer the chamber is a feasible alternative.

5.2 SEA ELEVATOR

There are no serious technological obstacles to the design and construction of a large bell, or sea elevator, which would have a depth range to 6,000 feet and payload capacity in excess of 5,500 pounds. A spherical pressure hull with variable ballast, mating skirt, life support system and a manipulator could be used for station resupply.

The elevator could be towed to the site, or carried aboard a support ship with suitable handling equipment. Guided by a taut buoy cable system the elevator could complete replenishment in a single dive in less than six hours of diving time. If the bell were equipped with small thrusters for fine maneuvering, the haul-down cable might be unnecessary.

In order to decouple the sea elevator from forces generated by surface waves, a stable platform is required. This requirement is not easily met. One method that has been suggested is that of utilizing a flip type vessel as an elevator shaft. The portion of the vessel which is submerged in the deployed position could be made as a hollow shaft slightly larger in diameter than the elevator hull. The vessel could thus transport the elevator, flip to its upright position and lower the elevator through the disturbed water column. The vessel would, of course, not provide a shaft to station depth, but only deep enough to assure stable descent and ascent.

Comparison of the Sea Elevator concept with that of a free swimming vehicle of equivalent payload capacity yields the information in Table 5-1.

TABLE 5-1

SEA ELEVATOR vs. VEHICLE

	ADVANTAGES	DISADVANTAGES
Elevator	Lower construction costs* Smaller and Lighter No usage priority problems Lower operating costs	Requires decoupling from surface Cables can foul Station More complex mating equipment No system for deep diving now planned or operational
Vehicle	DSRV under construction Greater flexibility of operation Can perform auxiliary functions	High operating costs High construction costs Subject to priority commitments

* Not including costs associated with a stable surface platform.

5.3 AERIAL RESUPPLY

Westinghouse and All American Engineering Company, Wilmington, Delaware, have jointly developed resupply concepts utilizing cargo aircraft and sea elevator type transfer capsules. All American Engineering has had considerable experience in the pick-up and delivery of men and equipment as described below and is now under contract to government agencies using these methods.

These concepts require that the Station access chamber be modified as shown in Figures 5-4 or 5-6 and that Station power be sufficient to operate a dewatering system for the access and winch chambers (Figure 5-4). The technologies involved are within current state-of-the-art.

5.3.1 Weekly Resupply

This system utilizes cargo aircraft to move supplies from a base to the submerged Manned Underwater Station (MUS). A sphere large enough to carry two men or consumables for one week is used.

A specially equipped aircraft carries the supply sphere to the Station site, where a float supported pick-up system, deployed from the access chamber pulls it out of the airplane. The sphere is winched down to the habitat and enters the access (transfer) chamber. The chamber hatch is closed and the chamber is then pumped dry. After the air pressure is equalized with that of the habitat, men enter the chamber to unload the supplies and then reload the sphere with items for the return trip. The sphere is allowed to rise to the surface, where the aircraft picks it up and returns it to the base for reloading. The sequence is depicted in Figures 5-2 and 5-3.

5.3.1.1 Delivery and Recovery Aircraft

The aircraft required for the supply mission has an aft loading cargo door and

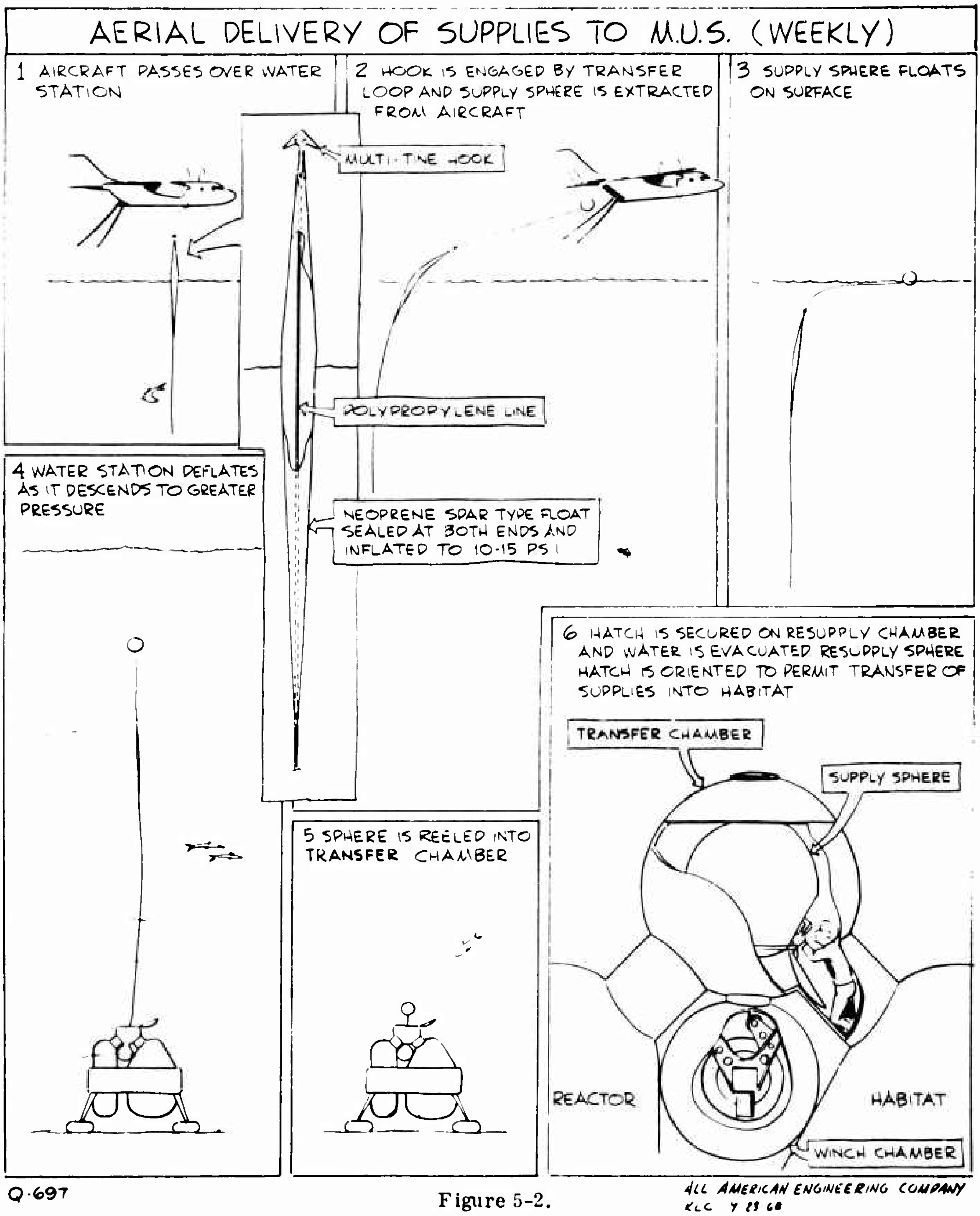

AERIAL DELIVERY OF SUPPLIES TO M.U.S. (WEEKLY)
1 AIRCRAFT PASSES OVER WATER STATION
2 HOOK IS ENGAGED BY TRANSFER LOOP AND SUPPLY SPHERE IS EXTRACTED FROM AIRCRAFT
3 SUPPLY SPHERE FLOATS ON SURFACE
MULTI-TINE HOOK
POLYPROPYLENE LINE
NEOPRENE SPAR TYPE FLOAT SEALED AT BOTH ENDS AND INFLATED TO 10-15 PSI
4 WATER STATION DEFLATES AS IT DESCENDS TO GREATER PRESSURE
5 SPHERE IS REELED INTO TRANSFER CHAMBER
6 HATCH IS SECURED ON RESUPPLY CHAMBER AND WATER IS EVACUATED RESUPPLY SPHERE HATCH IS ORIENTED TO PERMIT TRANSFER OF SUPPLIES INTO HABITAT
TRANSFER CHAMBER
SUPPLY SPHERE
REACTOR
HABITAT
WINCH CHAMBER
Q-697
ALL AMERICAN ENGINEERING COMPANY

Figure 5-2.

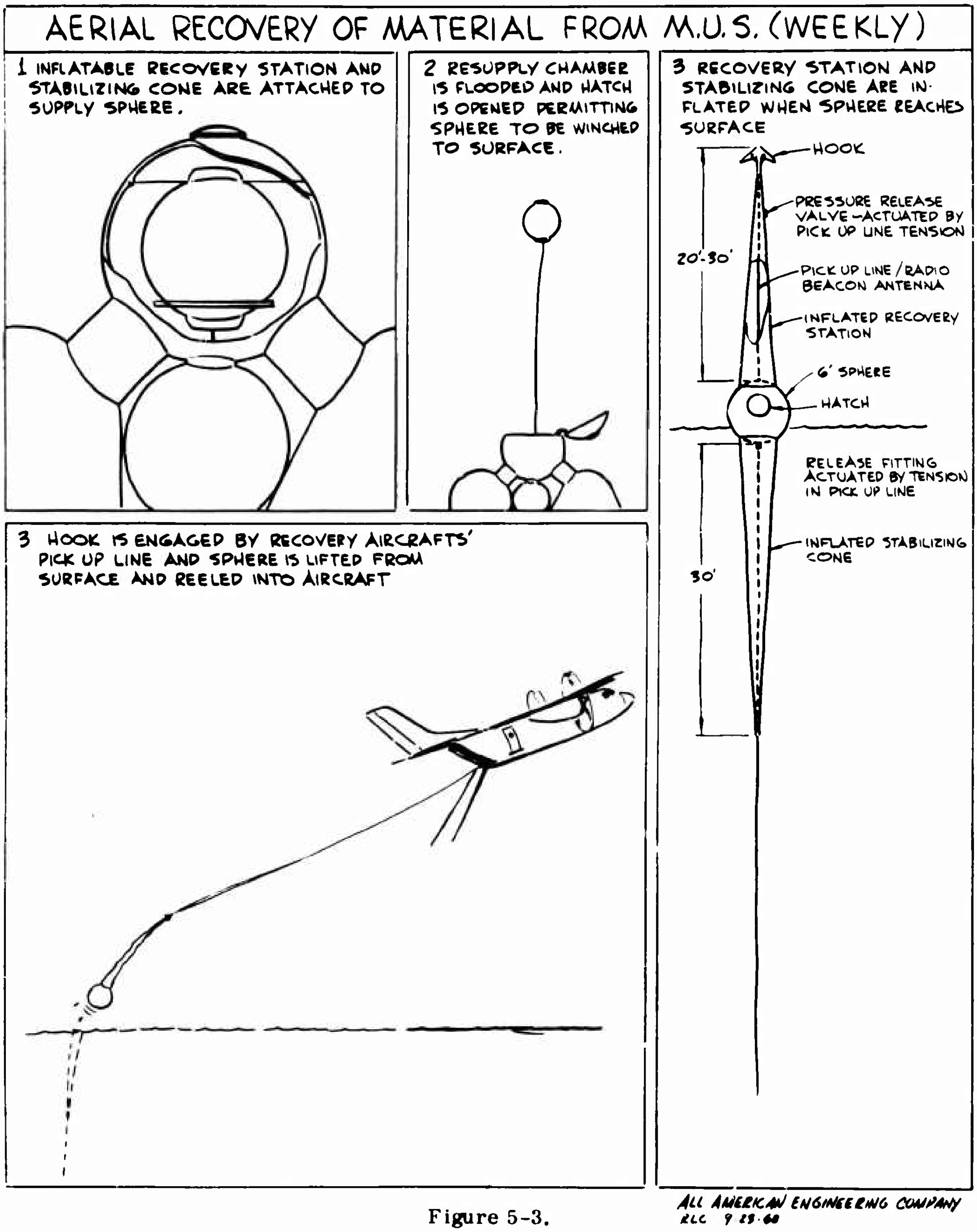

AERIAL RECOVERY OF MATERIAL FROM M.U.S. (WEEKLY)
1 INFLATABLE RECOVERY STATION AND STABILIZING CONE ARE ATTACHED TO SUPPLY SPHERE.
2 RESUPPLY CHAMBER IS FLOODED AND HATCH IS OPENED PERMITTING SPHERE TO BE WINCHED TO SURFACE.
3 RECOVERY STATION AND STABILIZING CONE ARE INFLATED WHEN SPHERE REACHES SURFACE
HOOK
PRESSURE RELEASE VALVE - ACTUATED BY PICK UP LINE TENSION
20'-30'
PICK UP LINE / RADIO BEACON ANTENNA
INFLATED RECOVERY STATION
6' SPHERE
HATCH
RELEASE FITTING ACTUATED BY TENSION IN PICK UP LINE
INFLATED STABILIZING CONE
30'
3 HOOK IS ENGAGED BY RECOVERY AIRCRAFTS' PICK UP LINE AND SPHERE IS LIFTED FROM SURFACE AND REELED INTO AIRCRAFT
ALL AMERICAN ENGINEERING COMPANY
RLC 9-23-60

Figure 5-3.

is capable of handling the six foot diameter supply sphere. A cradle and boom provide for the support and handling of the sphere. Two retractable recovery poles are mounted on the aft cargo floor. A recovery and handling winch is mounted in the forward cabin area.

The aircraft is equipped with a radio beacon locator, and other instruments needed to home in on the pick-up station.

The equipment in the aircraft is designed for quick installation and removal. Quick conversion of the aircraft avoids tying it up when not needed for the supply mission.

5.3.1.2 Supply Sphere

The supply sphere is capable of withstanding pressures at 6000 feet. It is six feet in diameter, slightly buoyant with load and is equipped with a 25-inch diameter hatch. The sphere has a bracket on top to which an inflatable pick-up station can be attached and a bracket on the bottom for attaching the stabilizing bag. A radio beacon transmitter, strobe light, or some other device for signaling the aircraft will be attached to the sphere.

5.3.1.3 Transfer Chamber

The transfer chamber (Figure 5-4) is a 9 ft. diameter sphere attached to the top of the MUS, between the habitat and reactor cylinders. The existing Station access chamber could be appropriately modified. It has a hatch large enough to permit entry of the supply sphere. A smaller hatch and mating platform for mating with a submersible vehicle could be built into the large hatch to provide the MUS with a back-up method of resupply. Two other hatches connect the transfer chamber with the habitat and reactor cylinders as in the reference Station.

A winch chamber is directly below the transfer chamber. Both chambers may be pumped dry and pressure equalized with the habitat.

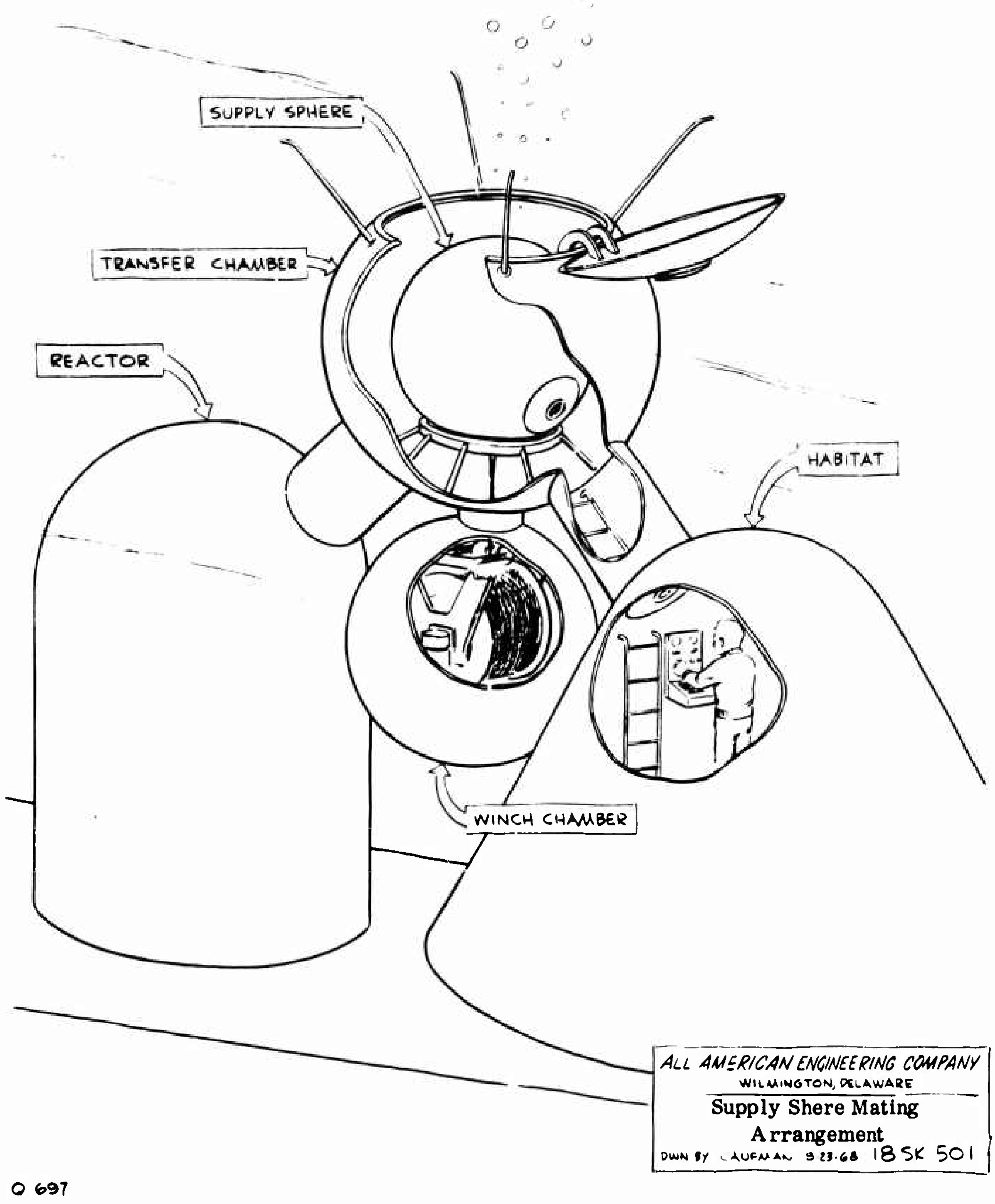

SUPPLY SPHERE
TRANSFER CHAMBER
REACTOR
HABITAT
WINCH CHAMBER
ALL AMERICAN ENGINEERING COMPANY
WILMINGTON, DELAWARE
Supply Shere Mating
Arrangement
DWN BY CAUFMAN 9-23-68 18 SK 501
Q 697

Figure 5-4.

5.3.1.4 Delivery

The sphere is loaded with supplies and placed on the aircraft cradle near the aft cargo door.

As the plane approaches the pick-up area, the Station lets out a line from the transfer chamber to which a pick-up system is attached. The system consists of a float, a pick-up hook, and a guidance device. In the ready position, the hook stands above the water level, supported by the float.

During preparation for the aircraft fly-by, a looped rope line assembly is attached to the sphere and supported below the plane by two pick-up poles. As the plane flies over the pick-up site at low speeds, the pick-up hook engages the loop, and the sphere is pulled out of the aircraft and splashes into the water.

After the winch has reeled the supply sphere down and into the transfer chamber, the large hatch is closed, the chamber pumped dry, and the air pressure equalized. Men now enter from the habitat, unload the supplies and place the waste material aboard the supply sphere.

5.3.1.5 Retrieval

A pressure actuated pick-up station is attached to the top of the sphere, and a stabilizing bag is attached to the bottom of the sphere. The transfer chamber is flooded, the hatch opens, and the sphere begins its winch controlled ascent to the surface. The pick-up station inflates automatically as the sphere nears the surface.

The aircraft flies by, engages the pick-up hook and takes the sphere in tow, breaking a weak link in the down-haul rope. The sphere is then brought on board the aircraft and returned to base for another resupply mission.

5.3.2 Monthly Resupply

This system utilizes aircraft and a Shuttle Chember which is normally mated to the Station (Figure 5-5).

A supply sphere and cylinder, loaded with men and a cargo package, is allowed to ascent from the MUS to the ocean surface. Upon reaching the surface, the men transfer the cargo from the supply sphere to the package in the cylinder. The aircraft picks up the package, winches it aboard, then lowers another package of supplies into the cylinder. The men transfer the supplies from the package to the sphere and prepare to descend. The sphere and cylinder are winched down to the MUS to be off loaded through the sphere bottom hatch into the transfer chamber. Figure 5-6 illustrates this method.

5.3.2.1 Delivery and Recovery Aircraft

The aircraft required for the supply mission has an aft loading cargo door and is capable of handling the cargo package. A cradle and boom provide for the support and handling of the package. Two retractable recovery poles are mounted on the aft cargo floor. A special recovery and handling winch is mounted in the forward cabin area.

The aircraft is equipped with a radio beacon locator and other instruments needed to home in on the pick-up station.

The equipment in the aircraft is designed for quick installation and removal. This allows the aircraft to be used for other purposes when not needed for the supply missions.

5.3.2.2 Transfer Chamber

The transfer chamber is attached to the MUS, between the reactor and habitat

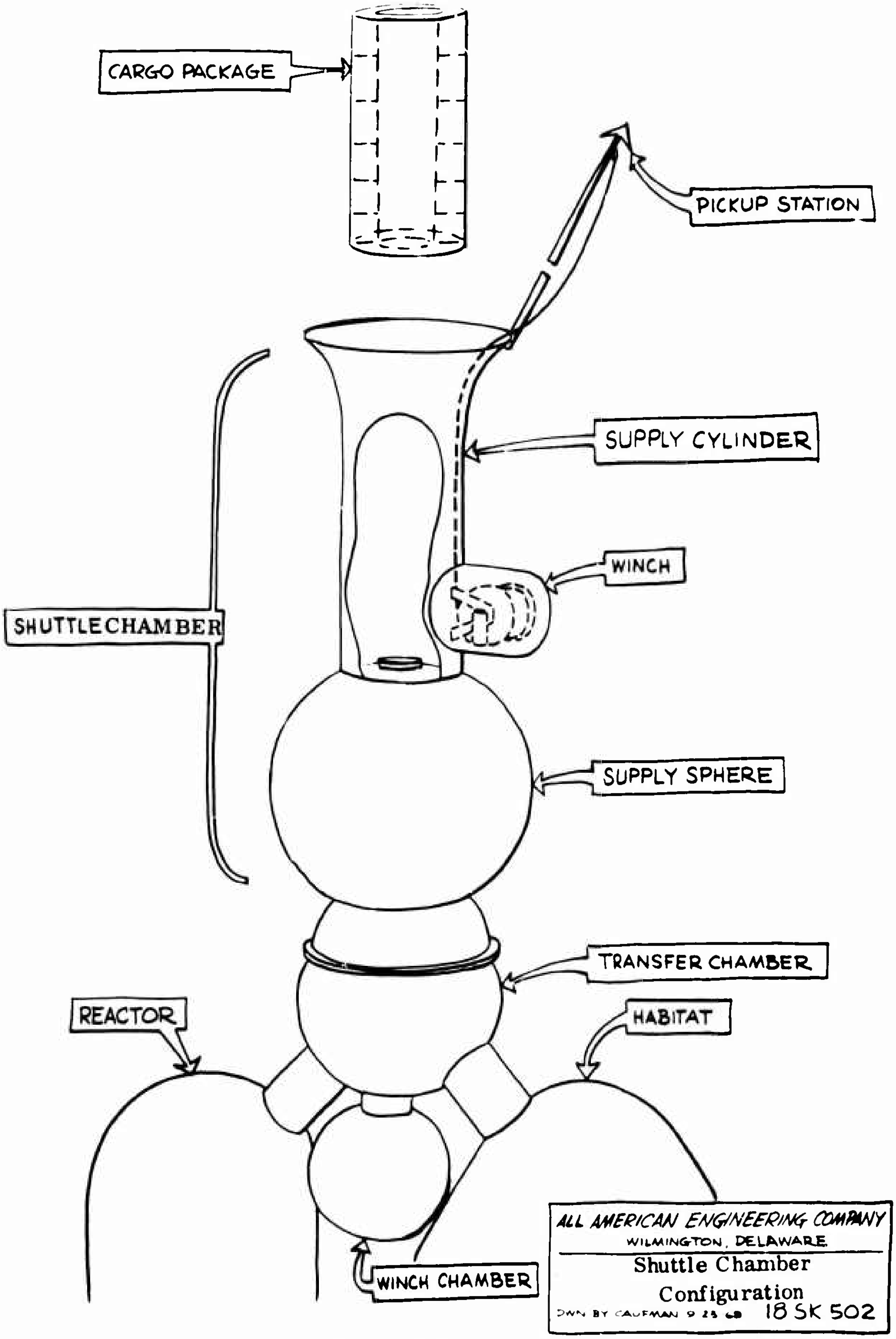


Figure 5-5

Q-697

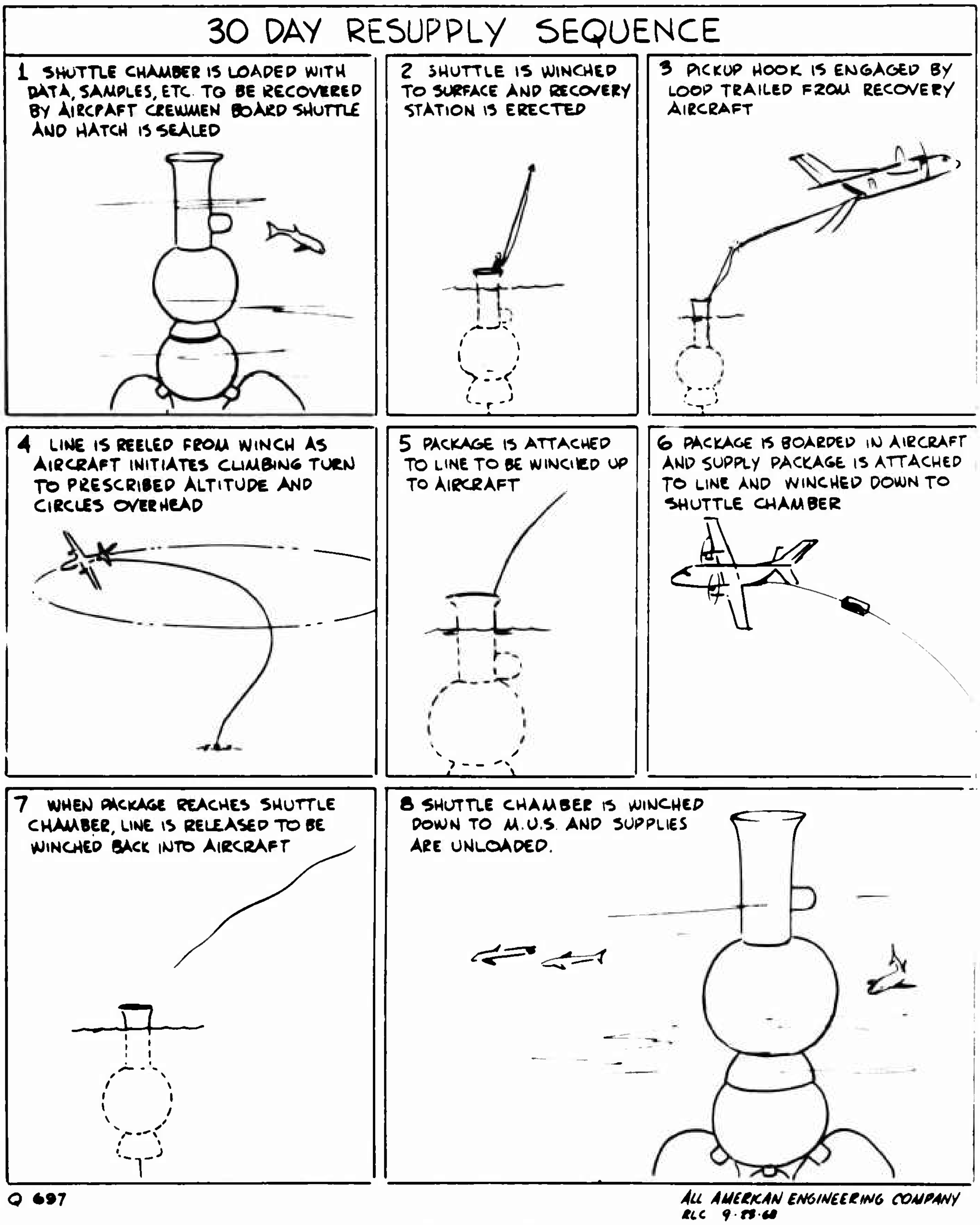

30 DAY RESUPPLY SEQUENCE
1 SHUTTLE CHAMBER IS LOADED WITH DATA, SAMPLES, ETC. TO BE RECOVERED BY AIRCRAFT CREWMEN BOARD SHUTTLE AND HATCH IS SEALED
2 SHUTTLE IS WINCHED TO SURFACE AND RECOVERY STATION IS ERECTED
3 PICKUP HOOK IS ENGAGED BY LOOP TRAILED FROM RECOVERY AIRCRAFT
4 LINE IS REELED FROM WINCH AS AIRCRAFT INITIATES CLIMBING TURN TO PRESCRIBED ALTITUDE AND CIRCLES OVERHEAD
5 PACKAGE IS ATTACHED TO LINE TO BE WINCHED UP TO AIRCRAFT
6 PACKAGE IS BOARDED IN AIRCRAFT AND SUPPLY PACKAGE IS ATTACHED TO LINE AND WINCHED DOWN TO SHUTTLE CHAMBER
7 WHEN PACKAGE REACHES SHUTTLE CHAMBER, LINE IS RELEASED TO BE WINCHED BACK INTO AIRCRAFT
8 SHUTTLE CHAMBER IS WINCHED DOWN TO M.U.S. AND SUPPLIES ARE UNLOADED.
Q 697
ALL AMERICAN ENGINEERING COMPANY

Figure 5-6

cylinders. This chamber could be the access chamber described in Section 2 with a winch sphere and dewatering capability added.

5.3.2.3 Shuttle Chamber

The shuttle chamber (Figure 5-5) consists of a supply sphere, twelve feet in diameter, with a cylinder on top. The supply sphere has two hatches. The bottom hatch is equipped with a skirt to mate with the hatch of the Station transfer chamber, and the top hatch allows access to the cylinder for the transfer of supplies. The upper end of the cylinder is open to the environment, and has a winch attached on the outer wall. The winch line controls the cargo package in its ascent to and descent from the aircraft.

5.3.2.4 Cargo Package

The cargo package consists of a liner for the shuttle chamber cylinder. The liner has shelves or compartments in which men or materials may be carried. The compartments must be moisture proof, but not pressure resistant since they will be emptied of cargo on the surface and flooded when the shuttle chamber is submerged.

5.3.2.5 Resupply Operation

The resupply operation begins with men from the habitat loading off-going cargo into the supply sphere. The hatches are sealed, and the shuttle chamber with cylinder liner ascend to the surface. The speed of the upward journey is controlled by the winch below the transfer chamber.

At the surface the cylinder and liner are pumped or drained dry. Power can be supplied via the winch cable from the Station.

The men open the sphere top hatch and transfer cargo to the cargo package in the cylinder. They then erect a pick-up station on top of the cylinder.

As the aircraft flies by, it engages the pick-up hook, and immediately begins paying out line. The plane goes into a climbing turn, and flies in a large circle.

The package is then winched into the aircraft, while the cylinder winch pays out line. The retrieved package is replaced by a fresh package, loaded with supplies.

The new package is winched back to the cylinder, while the aircraft winch pays out line. When the men have received the new cargo package in the cylinder, the line to the aircraft is disconnected.

The cargo is transferred from the cargo package to the sphere, and the sphere is prepared for the descent. The shuttle chamber is winched down to the MUS, and mates with the transfer chamber. The water is pumped out of the transfer chamber, and the supplies are carried through it into the habitat.

5. 3. 3 Summary

Aerial resupply as described in 5. 3. 1 and 5. 3. 2 requires no surface support ship and results in minimum time for the total resupply operation, particularly in areas distant from suitable ports. Problems of guiding the supply sphere to its final position at the Station are somewhat lessened by leading the downhaul cable through the center of the access sphere, however it is likely that some additional fine maneuvering methods would be required.

The major obstacles to these concept are the lifting capability of the aircraft, and the design of a suitable cargo package for the 30 day resupply. The supply spheres would be equipped similarly to the Sea Elevator in 5. 2 with the life support equipment and variable ballast system. If the method described in 5. 3. 1 (Weekly Resupply) is restricted to material delivery, no life support equipment is required.

6.0 PERSONNEL AND MATERIAL TRANSFER

6.1 PERSONNEL

Personnel will be transported between the surface and Station by the resupply vehicle. If a DSRV is used, the Station relief crew will assist in loading provisions aboard the vehicle, filling the aft sphere first, and will descend in the mid sphere.

When mating has been accomplished and vehicle and Station access hatches opened, men can be lowered into the access chamber with the electric cargo hoist. Simple canvas stirrups attached to the hoist hook will hold the passenger's feet and support his weight while he grasps the hoist line for stability (see Figure 6-1).

Able bodied men will ascend from the Station to the vehicle using the hoist and [illegible]s. A disabled crew member may be removed by strapping him into a standard [illegible] stretcher and passing him through the hatches using the hoist to support most of his weight.

6.2 PACKAGING

The maximum sizes of packages and equipment units to be transferred into the Station are dictated primarily by the minimum size hatch opening in either the Station or the resupply submersible. Both Station and DSRV conform to the U. S. Navy standard of 25 inches for the clear diameter of hatch openings in submarines. Allowance for adequate clearance to pass packages through these hatches requires that square package cross section dimensions do not exceed 15 inches by 15 inches (see Figure 6-2). The size of the basic units of life support equipments is fixed for compatibility with the Station life support subsystems. The dimensions of the chlorate candles and lithium hydroxide canisters are shown in Table 1-3. They are cylinders, approximately

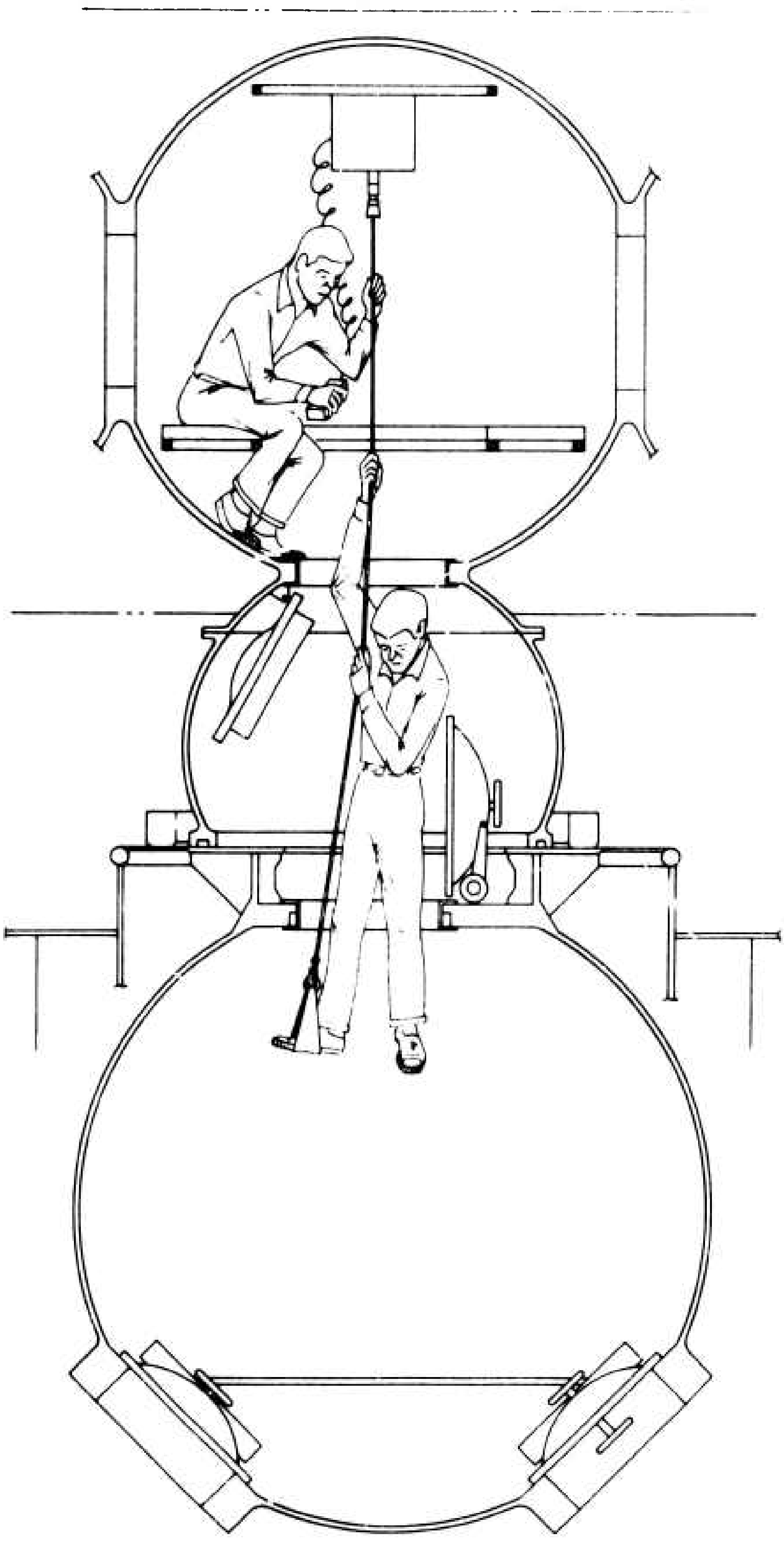


Figure 6-1. Personnel Transfer

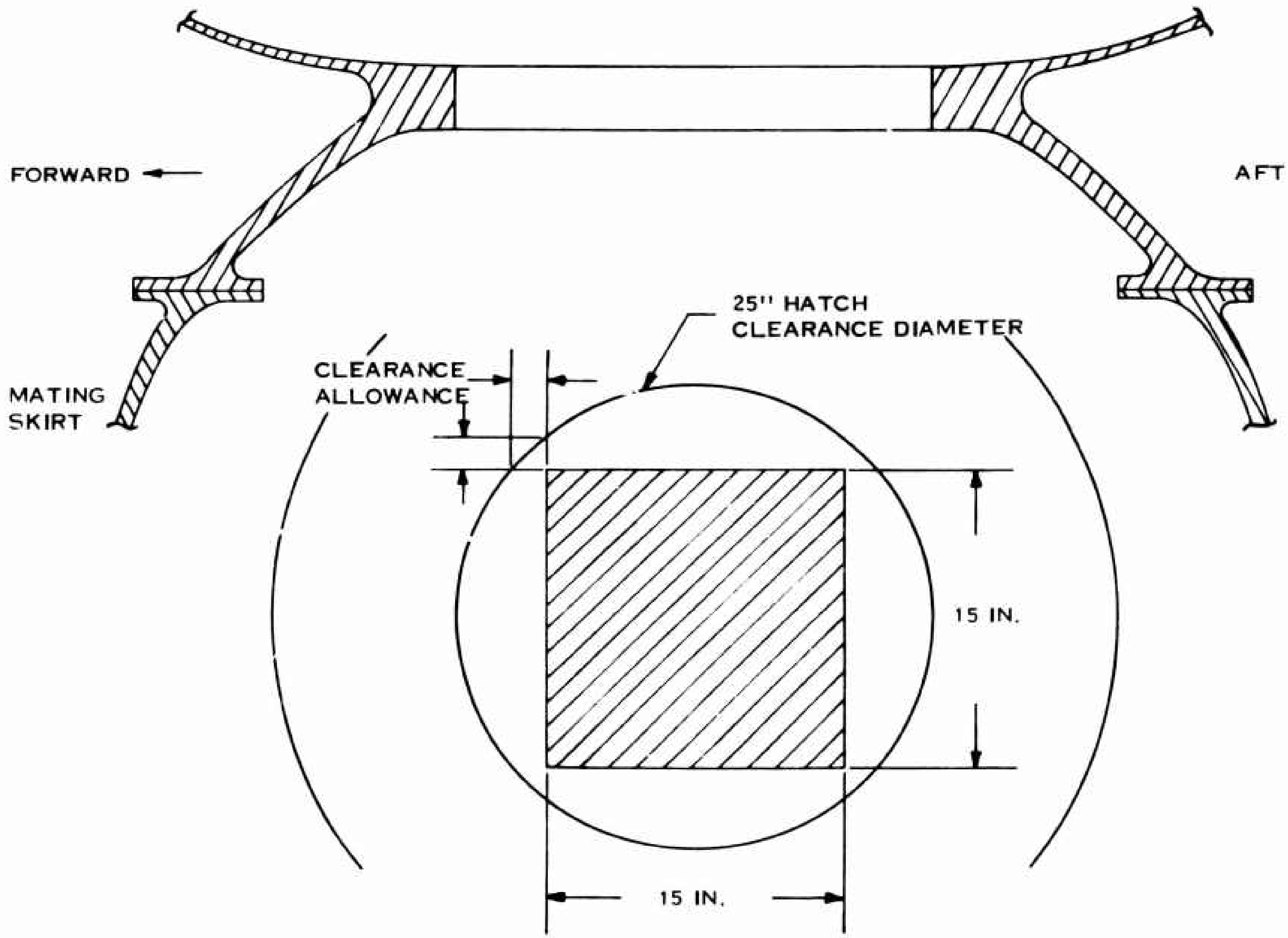


Figure 6-2. Maximum Package Cross Section

7 inches in diameter and 12 inches high, and may be bundled in twos or threes for handling convenience.

6.2.1 Food

Frozen food must be transferred in insulated chests to reduce the likelihood of thawing. Twenty-one such chests with outside dimensions of 15 by 15 inches square and 20 inches tall will provide sufficient volume allowing for insulation and wall thickness of up to 1-1/2 inches. Chests of this size will accommodate TV type meal trays as well as bulk items. Alternatively, cylindrical chests 16-1/2 inches outside diameter and 20 inches high would provide the same volume. However, since refrigeration storage is usually designed for square or rectangular shaped containers the square cross section chests are recommended. In order to keep the chests manageable by one man, the total weight of each should not exceed 35 pounds when filled. These same chests will be filled with perishable refuse during the 30 day mission cycle, stored in the Station refrigerator and transferred out during resupply operations.

6.2.2 Liquids

Because of the large volume of potable water (230 gallons) required, special containers are needed to transport the water in the limited storage space of the resupply submersible. Flexible neoprene tanks will be used to store the water aboard the submersible during the transit from the support ship to the Station. The flexible tanks are placed inside the submersible sphere while still empty and then filled with water after being fixed in place inside the sphere. Separate flexible neoprene tanks will also be used to carry the sanitary waste effluent from the Station.

Consideration was given to transferring both sanitary waste and fresh water in five gallon cans. Hoses running between vehicle storage tanks and habitat storage tanks would preclude rapid hatch closure in case of flooding and must hence be avoided. To transfer fresh water, 46 five gallon cans would be required. These cans could be carried to a pipe or hose fitting on A deck of the habitat and emptied to the storage tank

below D deck. The cans could then be used to transfer sanitary waste from the habitat to the vehicle. More sanitary waste is generated than fresh water is used however, so an additional 15 five gallon cans are required, making a total of 61 five gallon cans. Aside from the labor involved in handling these cans, severe storage and transportation problems arise, therefore, a scheme was devised to avoid this method. Interim storage tanks for the access chamber have been designed so that hoses run between vehicle and access chamber, and between access chamber and habitat storage tanks, but not at the same time. The liquid transfer sequence is included in the Resupply Plan, Section 2.4.

6.3 WEIGHT AND VOLUME CONSIDERATIONS

6.3.1 Vehicle Constraints

As shown in Section 1.3 the weight of personnel and material necessary to extend the Station mission capability 150 man days is 5,500 pounds. (An additional 150 pounds must be added to account for the weight of food chests to make a total weight of 5,650 pounds, however, since this adds less than 3% to the total, 5,500 pounds is considered to be the nominal weight requirement.)

The total volume requirement is 174 cubic feet for each 30 day cycle. If a packing factor of 70% is assumed for loading the resupply vehicle or Station access chamber, a stowage volume of 250 cubic feet is required for each one-way load.

The DSRV, as presently configured for rescue missions, has a nominal dry payload weight capacity of 4,800 pounds. The weight capacity can be increased, by removing one bank of propulsion batteries, to over 6,000 pounds. The removal of these batteries, which are located outside the pressure hull, is a relatively simple process and will not alter vehicle performance significantly for the resupply operation.

In the rescue configuration the DSRV has only approximately 144 cubic feet of dry stowage volume in the aft and mid spheres combined. Normal internal equipment, and the need for a clear area above the skirt hatch, restrict usage for cargo stowage (see Figure 6-3). In order to accommodate the full load of a 30-day resupply operation in one dive the DSRV aft sphere equipment must be rearranged or moved to another location in the vehicle. If all normal internal equipment is removed from the aft sphere, the useable volume in that sphere is approximately 380 cubic feet; 150 cubic feet more than the total necessary.

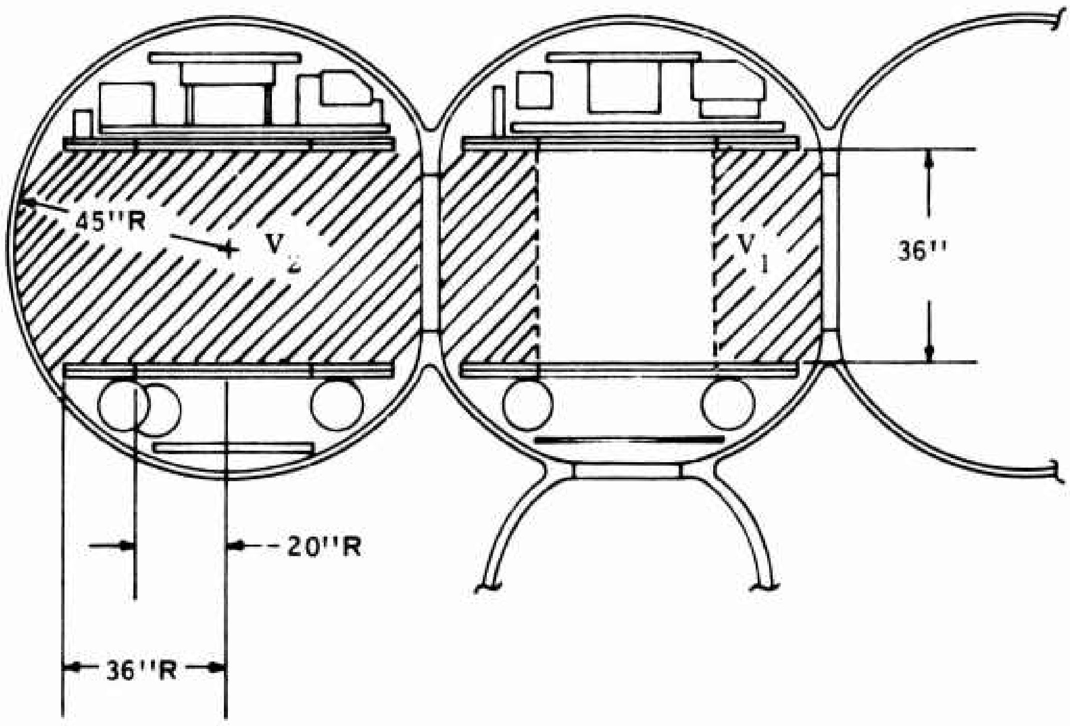
Weight and particularly the volume stowage requirements limit the number of alternate vehicles which can feasibly be used for resupply as discussed in Section 4.

6.3.2 <u>Access Chamber Constraints</u>

The single 9 foot diameter access sphere, as discussed in Section 2.3 is not large enough to accommodate both men and materials necessary for a 30-day resupply. Figure 6-4 shows a plan view of the access chamber containing the food, life support materials and liquid tanks arranged for maximum packing density. This stacking arrangement fills the chamber to within 15 inches of the chamber top above the food chests, and to within 2 feet of the top above the life support cylinders. Charcoal, filter and miscellaneous materials listed in Table 1-3 are not shown, but may be stacked in the remaining odd cavities. Even with this packing density insufficient space remains for 5 men and their personal effects. Thus, resupply must be performed by loading the chamber twice for incoming cargo and twice with outgoing cargo.

Since the arrangement shown in Figure 6-4 leaves no working space, the resupply sequence in Section 2.4 is recommended.

Other access chamber configurations considered in Section 7 provided more stowage space, but had disadvantages which precluded their selection.



MID-RESCUE SPHERE

$$V_1 \cong \pi\,(3^2 - 1.67^2)\,3 = \pi\,(9 - 2.8)\,3$$

$$V_1 \cong 59\ FT^3$$

AFT SPHERE

$$V_2 \cong \pi\,(3^2)\,3 = 85\ FT^3$$

$$\text{TOTAL VOLUME} = 59 + 85 = 144\ FT^3$$

Figure 6-3.

DSRV Useful Stowage Volume - Rescue Configuration

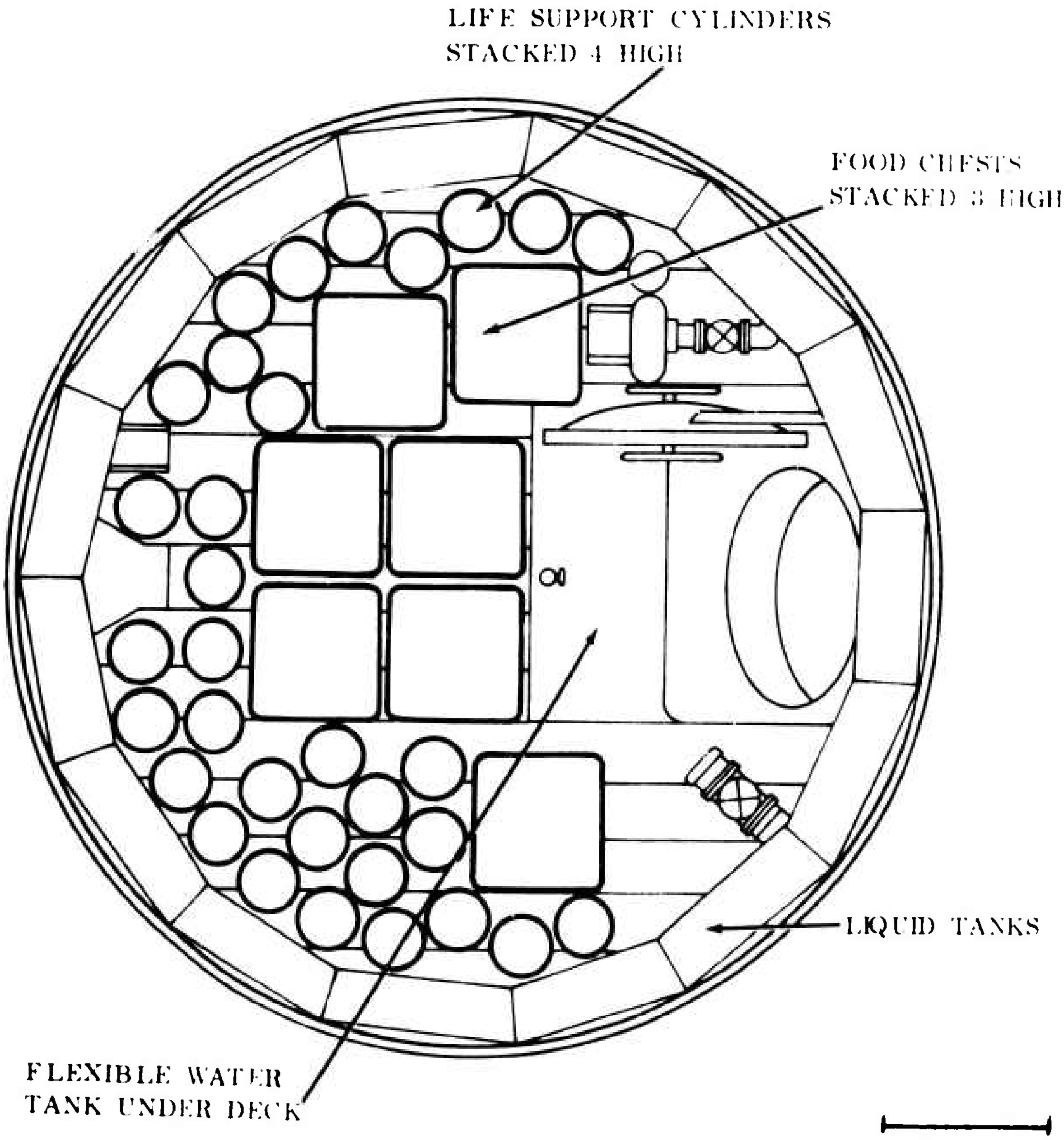


Figure 6-4.

Material Stacking Arrangement

6.4 MISSION EXTENSION

In order to extend the normal 30 day mission length without interim resupply, it is merely necessary to initially make multiple dives with the resupply vehicle, and to provide sufficient stowage space in the Station for the increased supply requirements. Additional stowage volume might be made available in the reactor cylinder if other power sources (i. e., shore power) are utilized. Figure 6-5 and 6-6 show the supply requirements for extended mission periods.

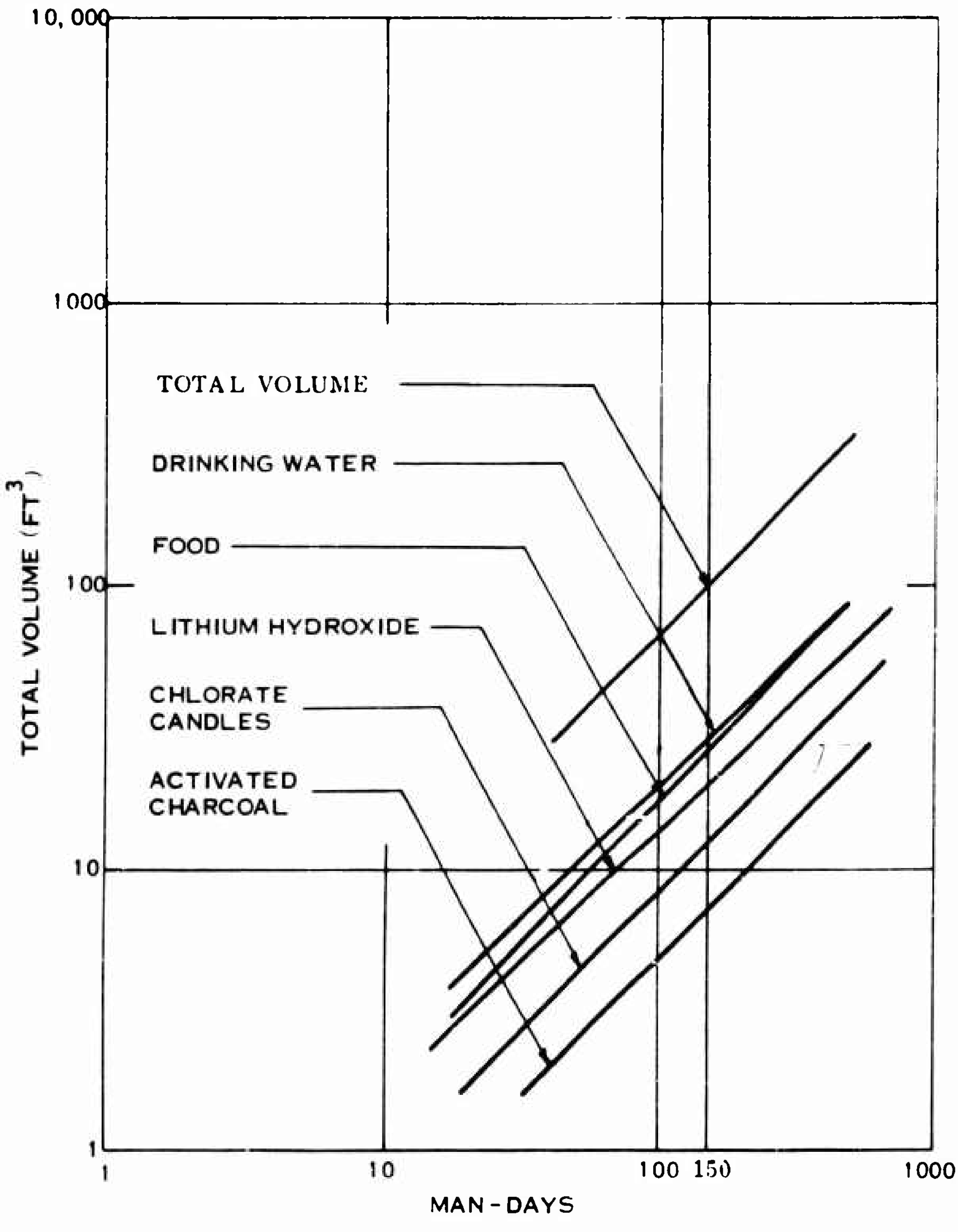


Figure 6-5.

Station Resupply Requirements (Volume)

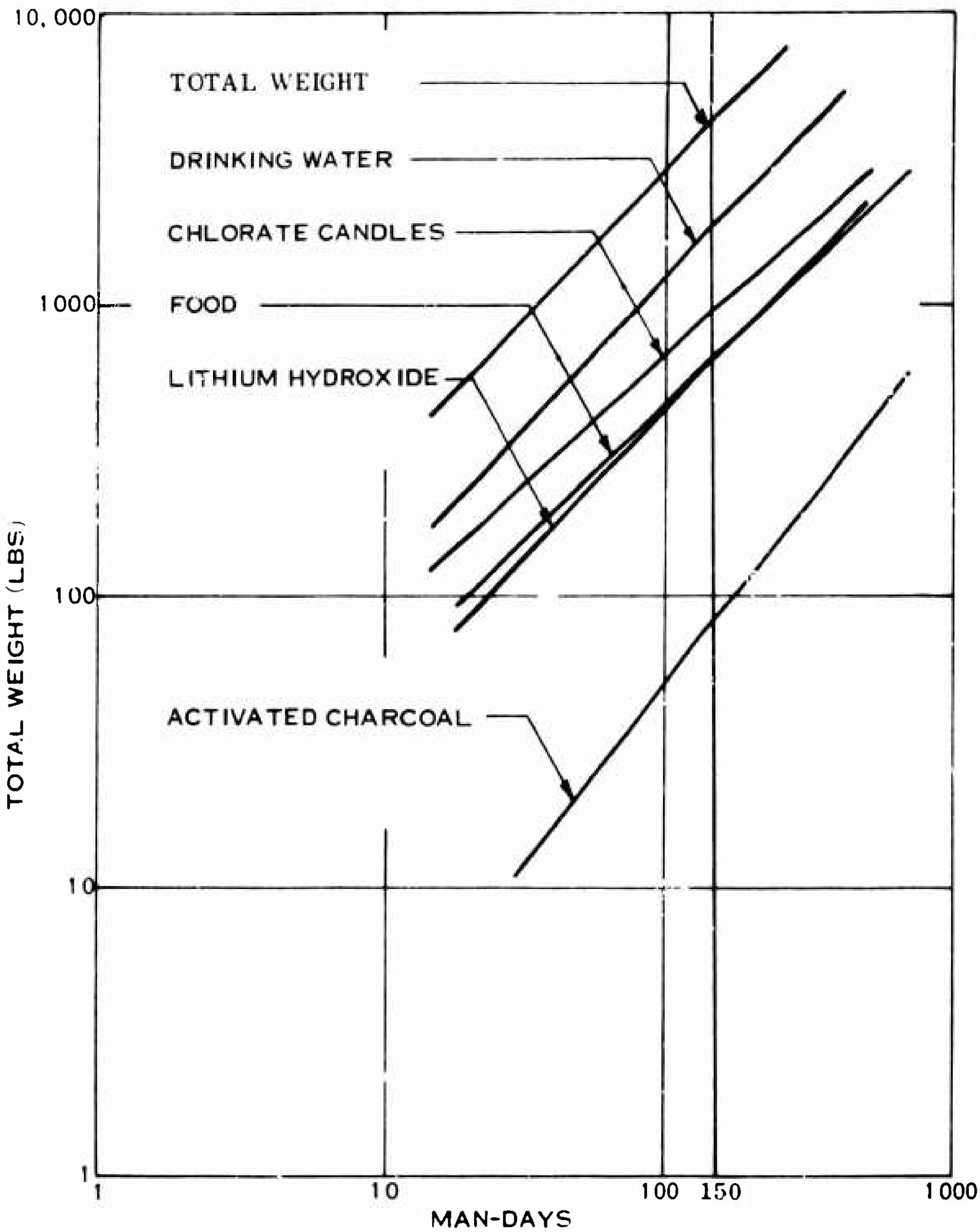


Figure 6-6.

Station Resupply Requirements (Weight)

7.0 ACCESS CHAMBER CONCEPT SELECTION

As part of the system design effort the existing conceptual access chamber was analyzed and compared with several concepts developed during the study. The attributes of each candidate configuration were evaluated and a final concept selected in cooperation with Navy technical personnel.

7.1 CRITERIA

Throughout the candidate concept development phase of this study significant changes to the overall configuration of the conceptual Station were avoided. Center of gravity, center of buoyancy and general outline of the station were modified only where overriding factors such as safety or efficiency dictated. At the same time, compatibility with predicted station expansion (i. e., the addition of a second habitat cylinder) was considered.

At maximum station operating depths severe constraints are placed on pressure hull configuration. Because of materials strength limitations and lack of knowledge of stress patterns in complex geometrical shapes, attention was focused on spherical pressure hulls or cylindrical hulls with end caps of spherical sections. Penetrations and pressure hull intersections were considered only in spherical sections.

Safety of the station and vehicle crew is paramount. Most potential hazards exist from the time the vehicle contacts the mating seat on the station until the vehicle departs after a resupply cycle. Impact between vehicle and station can damage the mating skirt or seat, or disturb stress patterns in the access chamber or vehicle sufficiently to cause failure. Thus, every attempt must be made to effect an easy landing.

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When the vehicle has safely landed on the station, the skirt cavity has been pumped dry and the interconnecting hatches opened, danger is not diminished. Seal failure between skirt and seat, matter how small, can be disasterous. A pin-hole leak first admitting a tiny stream of water, will, at 6,000 feet be under 2,700 psi pressure. Inside the access sphere visibility will be impaired for the water will vaporize immediately upon expansion in the chamber. Hydraulic jet action will quickly erode the gasket admitting more and more water. In the event of a leak the only possibility of escape for the crew member in the access chamber will be into the adjoining station chamber. For this reason egress from the access chamber should be made as easy as possible, and the interconnecting hatch placed as high as possible to keep it above the rising water level long enough for escape. If egress from the access chamber is directly into the habitat cylinder through a hatch, this hatch must be opened, escape effected and the hatch closed, before water in the access chamber inhibits hatch operation or floods the habitat. If, however, an intermediate chamber with two hatches is provided, probability of escape is increased while the habitat cylinder remains unexposed to flooding.

Should the station be exposed to water currents of unexpected magnitude while the vehicle is mated, overturning moments may endanger station stability, if no seal failure occurs. In order to minimize risk the vehicle should be mated to the access chamber for as short a length of time as possible, thus efficiency of materials transfer is important. As a safety measure, there will always be a closed hatch between the mating surface and the habitat so as to confine the flooding in the event of a seal leak. All supplies must be locked in and locked out using the access chamber as a lock.

The number of lockin-lockout cycles must be kept to a minimum to lessen vehicle mating time. Therefore, the ideal system would permit the entire loading and unloading operation to be performed with a single cycle. This in turn, requires that the volume and floor space available in the access chamber be sufficiently large to accommodate

the entire thirty day supply of provisions and the material to be off-loaded, and that a vehicle of similar capacity be available.

7.2 SINGLE ACCESS SPHERE

Initial effort was devoted to evaluation of the access chamber concept as developed in the Station draft report. This is a single 9 foot diameter sphere located as shown in Figure 7-1. Considerable effort has been applied by the designer of the concept Station to integrate this configuration with the Station structure. Scale model tank tests have been performed to assure stability under operating conditions and a significant data back-up has been developed. The design has merit in that it is relatively simple structurally and fabrication is feasible with current manufacturing processes.

There are however several disadvantages to this concept. There is insufficient volume to accommodate more than about one half the total resupply load of men and materials (see Section 6.3). As a result, the chamber must be loaded and unloaded four times during the resupply operation: twice for fresh crew and materials and twice for outgoing cargo.

The single sphere provides only one exit from the Station. If sufficient damage occurs to the access hatch or mating surface to preclude vehicle mating, personnel will be trapped until the Station can be brought to the surface.

The geometry of the single 9 foot spherical configuration necessitates a connecting hatch to the habitat that is below the chamber deck plates. In case of an access hatch, or mating seal leak this hatch will rapidly become inaccessible to crew members in the chamber (see Section 7.1).

7.3 DUAL ACCESS SPHERES

In order to achieve an increase in interim stowage space and at the same time provide dual hatches and mating seats as a safety precaution, a configuration with two access spheres was developed. These spheres were arranged as shown in Figure 7-2. Seven foot spheres were first considered which had the advantage that they could be

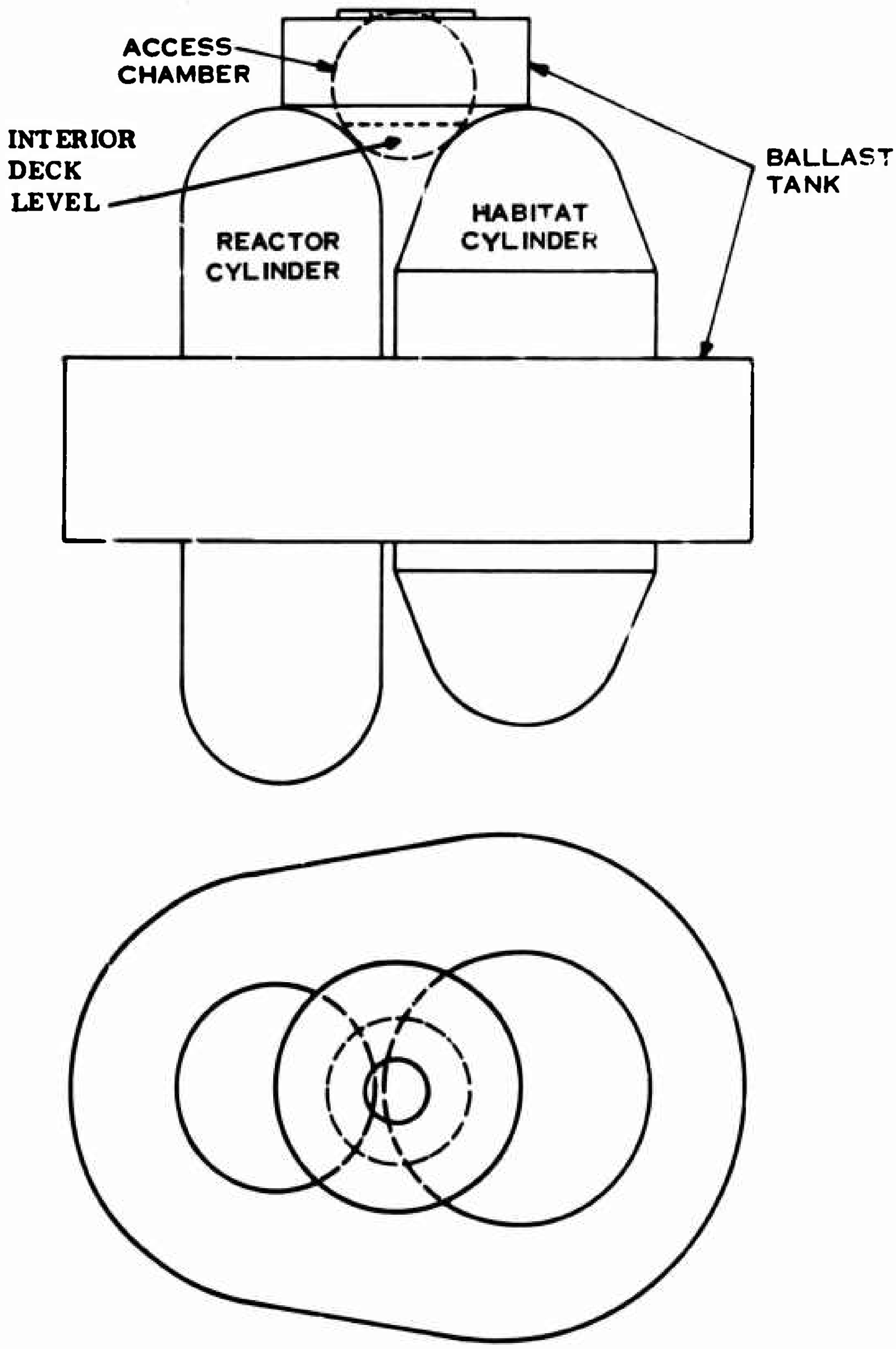

Figure 7-1.

System Using Single 9 Foot Sphere

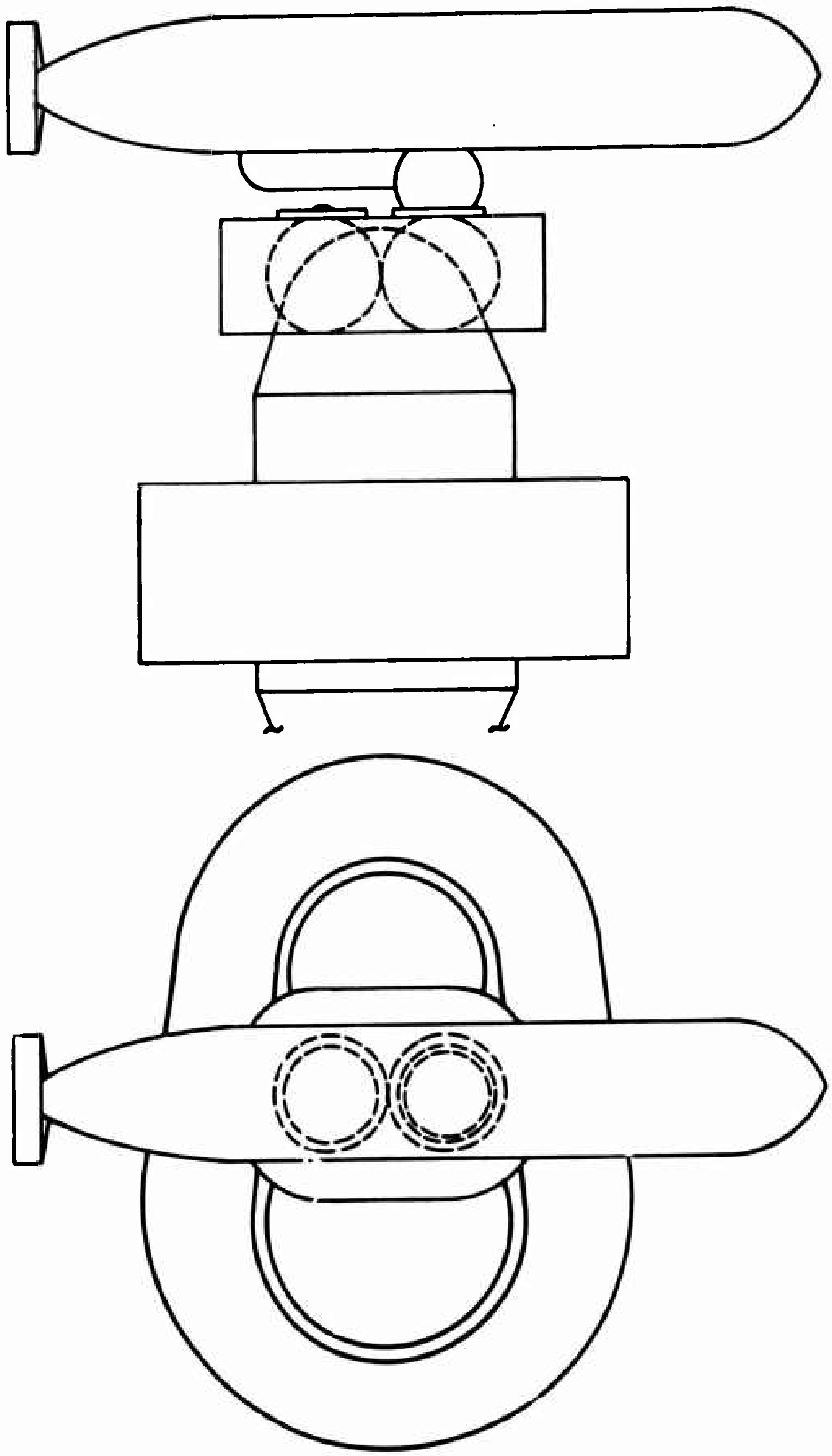

Figure 7-2.

System Using Two 7 Foot Access Spheres

placed lower on the habitat dome, thereby locating the hatches to habitat and reactor above the floor plates. (Structural constraints limit access sphere/cylinder intersections to those between spherical sections). Little improvement in floor space was realized however. The resulting chambers provided less than half of that needed for optimum operation.

Nine foot twin spheres were next considered as shown in Figure 7-3. These provided about one-half of that required for the optimum. However, the use of nine foot spheres forced placement of cylinder hatches below the floor level as with the single 9 foot sphere.

One disadvantage in the use of twin access spheres is that in order to utilize the space available, an extra step is required to move provisions from the sphere which is mated to the vehicle to the other sphere, and then back again when the provisions are moved into the habitat. Alternative procedures, depending on the number of hatches provided, are available. For example if each access sphere has connecting hatches to each cylinder, materials could be transferred more rapidly, but at the expense of added weight and structural complexity. There is also the consideration that should damage to a mating surface produce flooding in one sphere, it is questionable that normal operations would continue despite the availability of an alternate access.

7.4 REACTOR CYLINDER ACCESS

In order to avoid the undesirable characteristics of the single and dual access sphere configures, a plan to utilize the reactor cylinder dome was conceived. Figure 7-4 is a cutaway view of the concept. This arrangement provides space enough so that the access sphere can be loaded with off going material prior to the arrival of the transfer vehicle. After mating is accomplished resupply is a simple matter of bringing down new provisions into the access sphere and loading the off going material from the

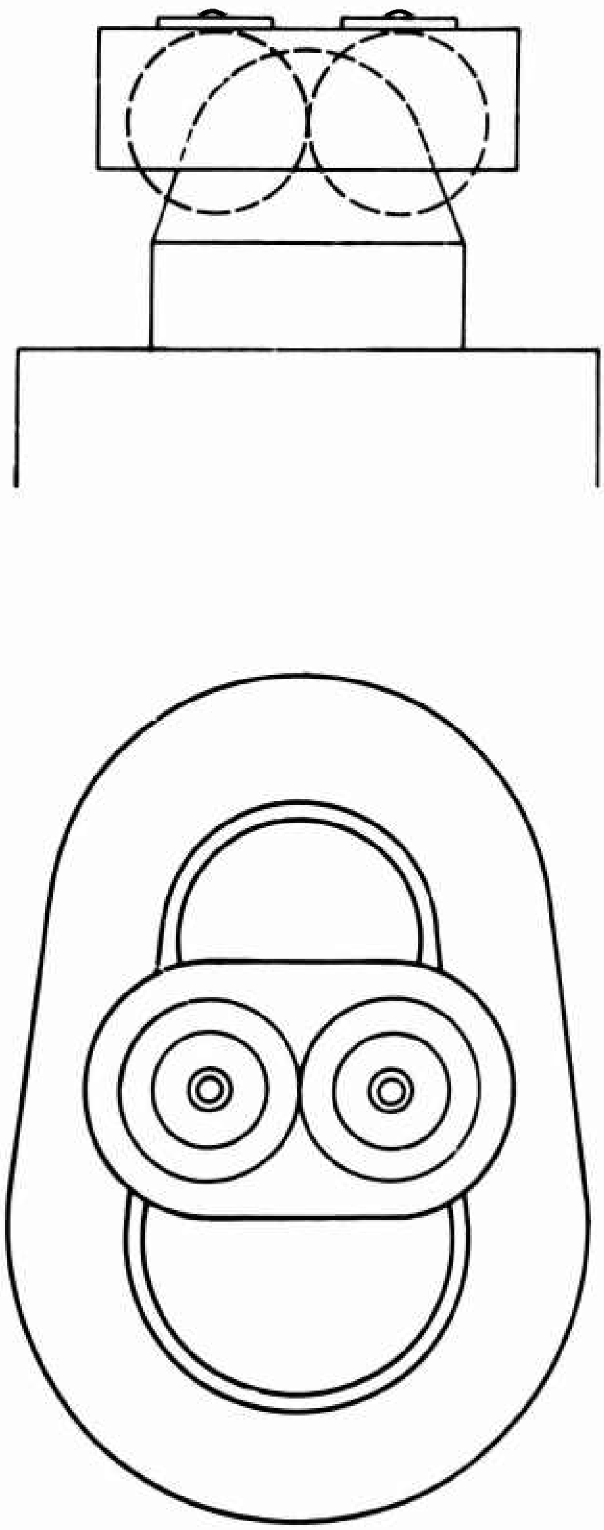

Figure 7-3.

System Using Two 9 Foot Access Spheres

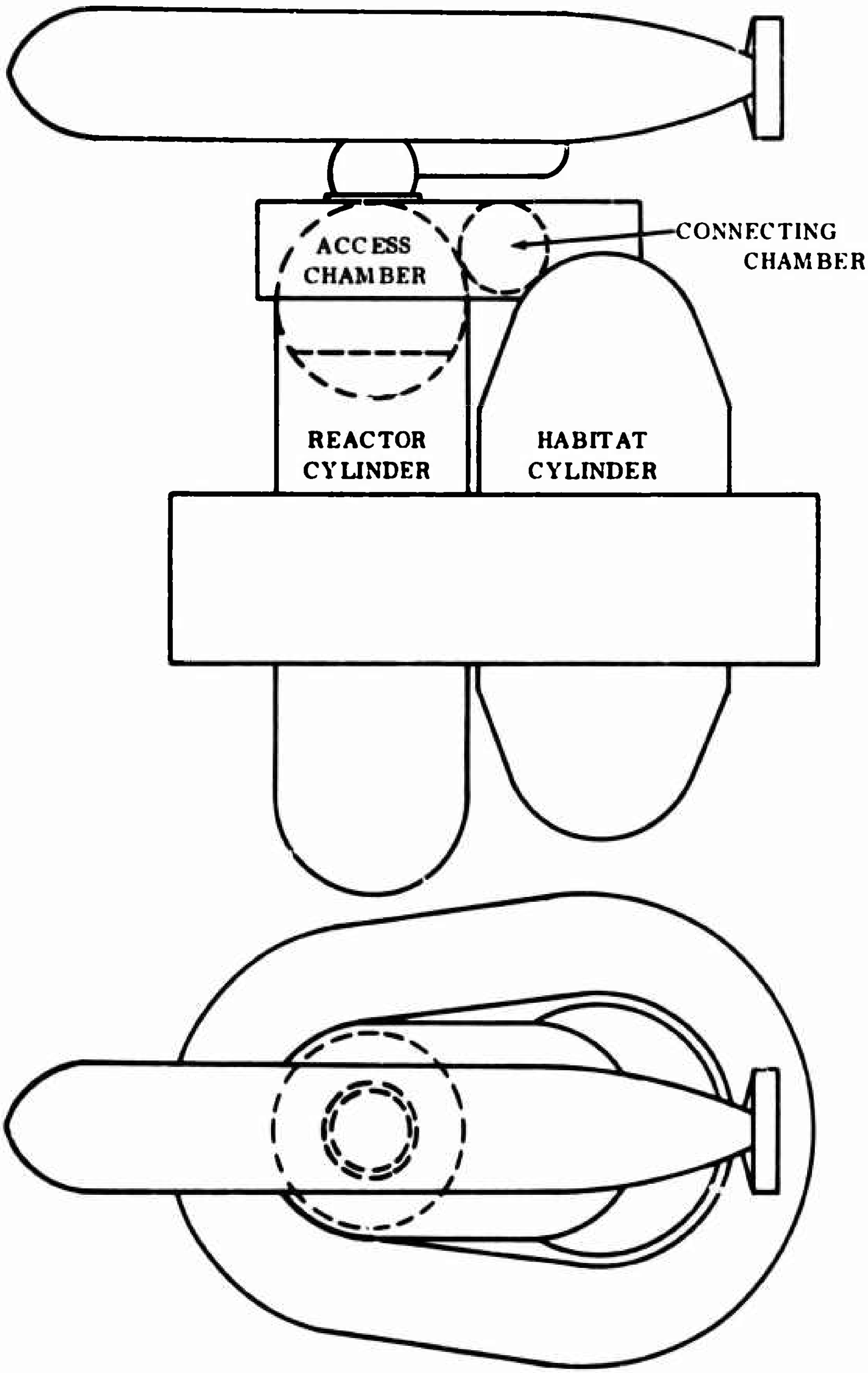

Figure 7-4. System Using Reactor Cylinder for Access

access sphere to the vehicle. The only opening and closing of hatches required while the resupply vehicle is mated is that involved in the exchange of personnel.

This configuration with the access chamber inside the reactor cylinder has a number of desirable features. The geometry provides for access to the habitat through a hatch which is well above the floor plates and thence through an interconnecting chamber. Should leakage occur at the mating seat, water will run to the bottom of the access chamber, the connecting hatch will remain above water for a time and the probability of escape for men in the access sphere is increased without jeopardizing the habitat. The fact that the vehicle mating platform is supported by the reactor cylinder rather than the interconnecting sphere with weld joints to both cylinders may add structural integrity to the system. In addition the larger chamber could be used for storage throughout the mission.

A disadvantage to this configuration is that some additional labor in transferring cargo through the connecting chamber is necessary, however this labor is performed before and after the resupply vehicle visit and does not result in extended mating time.

Construction of the sphere inside the reactor cylinder will follow the same principles as are used in the design and construction of the conceptual Station (see Figure 7-5). The upper hemisphere of the reactor cylinder will remain unchanged except for the addition of the upper hatch and its associated vehicle mating platform. This upper hatch will necessarily be a face seal type and will be made 30 inches in diameter so that dockside maintenance and refueling of the power plant can be performed. The hatch between access chamber and power plant machinery space is a 30 inch, face seating hatch which resists pressure from either side.

The lower hemisphere is attached to an adaptor which provides a smooth transition between the hemispherical section and the reactor cylinder. The interposition of this adaptor raises the upper hemisphere three feet above that in the concept design.

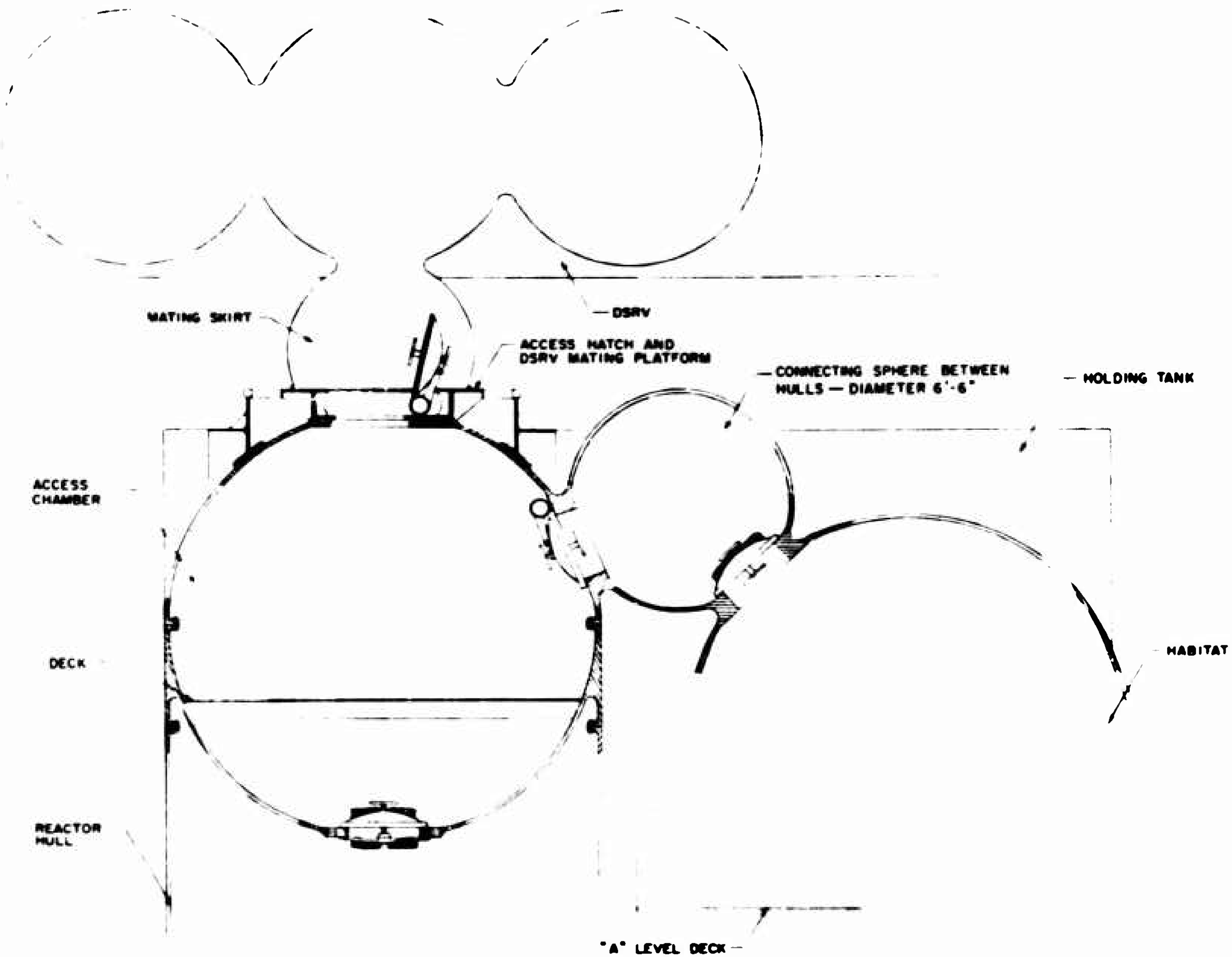

Figure 7-5. Reactor Cylinder Access Arrangement

but in spite of this, with the use of a smaller connecting sphere between hulls, the center of gravity of the entire Station is effectively lowered. The increase in volume which the additional three feet of reactor cylinder affords produces an increase in buoyancy high on the assembly, and this results in raising the center of buoyancy. This double effect should materially improve the stability of the Station. The hemispheres and the adaptor are attached by shrink fit bolts following the same assembly procedure as is described for the basic reactor cylinder in the Station draft report.

The lower portion of the hemisphere projects into an area which was previously allotted to machinery, but this encroachment amounts to only slightly over three feet. Inasmuch as the reactor has not yet been designed, it is likely that allowances could be made for the resulting reduction in space. If necessary, the lower end of the reactor cylinder could be lengthened to compensate.

Nuclear radiation hazards are not increased by this arrangement. The reactor must be designed such that radiation levels in the upper machinery space are low enough to permit men to make adjustments and minor repairs. Thus with the additional shielding provided by the heavy steel hemisphere, radiation levels in the access sphere would be tolerable.

7.5 CONFIGURATION SELECTION

Attributes of the four candidate concepts are summarized in Table 7-1. It is evident that the Reactor Cylinder Access system had several advantages over the other systems considered provided that the necessary alterations to the conceptual Station configuration were permissible. Since NCEL advised otherwise, preference shifted to the existing single 9 foot sphere on the basis that dispite other considerations, the advantage of preserving the original concept configuration outweighed uncertainties generated by changes in Station structure.

Hence the single 9 foot sphere was retained for the Ingress-Egress System.

TABLE 7-1.
COMPARISON OF CANDIDATE ACCESS CHAMBER CONFIGURATIONS

CONFIGURATION	ADVANTAGES	DISADVANTAGES
Single 9 foot diameter sphere (existing concept)	1. Maintains existing configuration 2. Structurally simple	1. Provides interim stowage for only 1/4 total in-out resupply load. 2. Habitat hatch below deck level 3. Single access only
Dual 7 foot spheres	1. Habitat hatch above deck level 2. Provides secondary access 3. Increased interim stowage volume	1. Interim stowage for only 2/3 total in-out resupply load 2. Requires extra step for cargo transfer 3. Structurally complex 4. Alters existing concept markedly
Dual 9 foot spheres	1. Provides secondary access 2. Increased interim stowage volume	1. Stowage volume still only 1/2 optimum 2. Extra step for cargo transfer 3. Structurally complex 4. Habitat hatch below deck level 5. Alters existing concept markedly
Reactor Cylinder Access	1. Provides stowage for total in-out load 2. Habitat hatch above deck level 3. Station stability improved 4. Provides additional isolation between vehicle and habitat 5. Practical for additional mission storage	1. Alters existing concept 2. Provides single access only 3. Necessitates additional labor (but not mating time) for resupply 4. Encroaches on reactor cylinder space

8.0 OUTLINE SPECIFICATIONS

The Ingress-Egress System (IES) for a Manned Underwater Station (MUS) includes the resupply vehicle, the Station access chamber and all interfacing equipment. Outline specifications for the prime resupply vehicle are described in Circular of Requirements for Design and Construction of Deep Submergence Rescue Vehicle (DSRV) (Prototype), U. S. Navy Special Projects Office, 28 September 1965. Requirements for mating equipment, navigational capabilities, and vehicle structure are included.

The Station access chamber concept has been developed by General Dynamics Corporation and is, by selection, functionally adequate for the system. Requirements for the chamber are outlined in Report N62399-67-C-0044. Station subsystems such as hatches, mating platform and communications are included.

The following outline specification covers equipment which is not part of the system as described in the two documents above. This includes access chamber subsystems, containers and handling equipment and modifications to the DSRV internal arrangement.

NAVAL CIVIL ENGINEERING LABORATORY
Outline Specification
1 October 1968

INGRESS-EGRESS SYSTEM EQUIPMENT,

SPECIFICATION FOR

1. SCOPE

This specification sets forth the requirements for equipment for an Ingress-Egress System (IES) that will enable the transfer of men and material between a Manned Underwater Station (MUS) and a submersible vehicle such as the Deep Submergence Rescue Vehicle (DSRV).

Specified equipment includes hose and containers for handling and temporary storage of potable water and sanitary waste; and platforms, crane, and chute for food, incidentals, and other packages.

This specification also covers equipment necessary for lighting and ventilation of the access sphere portion of the MUS during transfer.

2. APPLICABLE DOCUMENTS

2.1 Government publications. The following documents of the issue in effect on the date of invitation for bids form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

MILITARY

STANDARDS

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-100	Military Standard Engineering Drawing Practices

DRAWINGS

NCEL 1085809	MUS Ingress-Egress System, DSRV Access Sphere Interface
NCEL 1085810	MUS Ingress-Egress System, Access Sphere Habitat Interface

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

ASA B33.1	American Standard Hose Coupling Screw Threads
ASA B26	American National Fire-hose Coupling Screw Thread

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3. REQUIREMENTS

3.1 Environment. The IES equipment will operate in a submarine environment. The several items will be installed in the DSRV, in the MUS access sphere, or on the uppermost deck of the MUS habitat as indicated on the drawings. There will be no temperature or humidity control in the access sphere during a 30-day mission. Occasional salt water spray may be experienced in the access sphere.

3.2 Materials. All materials used in construction, fabrication, or testing of the IES furnishings shall have no adverse effect on the health of personnel when used for their intended purposes. Furthermore, such materials shall not emit irritating or unpleasant odors to the confined atmosphere; and all materials that contact the potable water shall not impart any taste or odor to the water.

Any materials used shall be suitable for the intended service, and shall be selected with consideration to corrosion resistance in a salt atmosphere and in proximity to other materials during storage and service. Compatability of materials shall be a major consideration.

All materials shall be subject to approval by the Government.

3.3 Design. It shall be the design objective of the IES equipment, when properly installed, to permit safe and efficient transfer of personnel and materials in a minimum time. All removable units and components must be quickly and readily assembled and disassembled to each other using the fittings provided under this specification. Safety, suitability, service life, and weight shall be given proper attention in equipment design.

3.3.1 Drawings. Shop drawings shall be submitted by contractor to depict items of structure, equipment, furnishings, fittings, or fabricated materials to be furnished under the contract. Shop drawings are not required for standard catalogue items or for minor details.

Drawings shall be made on tracing paper, plastic sheets, or linen by clear, sharp pencil lines of sufficient density to assure clear reproductions.

Drawing format and sizes shall be in accordance with MIL-STD-1000.

3.4 Reliability. The IES furnishings shall be designed to provide a 0.99 probability of performing their specified functions in the environment defined herein without failure for one resupply cycle.

3.5 Construction. All liquid containers and liquid transfer components shall be capable of leak-free operation when the containers are alternately filled and emptied approximately every 30 days over the specified service life of the equipment (3.4). If continuous service should be impractical for any item, contractor should so state, and should identify the item and recommend (in his bid) a replacement time period.

All braces, foundations, and fastening devices necessary to secure the equipment in its intended place of installation shall be supplied with the IES furnishings. Equipment shall be constructed so that it is unnecessary to perform welding or drilling on any pressure sphere during installation. All equipment must be removable to permit cleaning and painting of surrounding and adjacent structure, fittings, and walls, including the access sphere walls behind the potable water and sanitary waste tanks.

3.5.1 Hose coupling screw threads. Hose fittings shall comply with accepted standards as follows:

a. Fresh water transfer hose -- 1-1/2 inch, American Standard Hose Coupling Screw Threads (ASA B33.1).

b. Sanitary waste transfer hose -- 2-1/2 inch, American National Fire Hose Coupling Screw Thread (ASA B26).

3.6 Maintainability. All critical or replaceable items shall be designed and fabricated so as to facilitate removal and replacement.

3.7 Transportability. There are no applicable requirements.

3.8 Performance characteristics. Performance characteristics are outlined herein under 3.3, 3.5, and 6.1.

3.9 Details of components

3.9.1 General. The components of the IES equipment covered by this specification are categorized by function as:

a. potable water equipment
b. sanitary waste equipment
c. supply handling equipment
d. utility equipment
e. safety equipment
f. power distribution equipment

Specific requirements are given in the following paragraphs. Item numbers refer to component identification on the accompanying drawings.

3.9.2 Potable water equipment. The potable water equipment consists of:

a. Bag type fresh water tank with fittings, in the DSRV after sphere (Dwg. 1085809, Item 21).

b. Flexible underdeck fresh water tank with fittings, in the access sphere (Item 8).

c. Fresh water holding tanks with fittings, in the access sphere (Item 3).

d. Fresh water transfer hose (Dwg. 1085809, Item 11 and Dwg. 1085810, Item 25).

e. Fresh water filling manifold (Dwg. 1085810, Item 19).

3.9.2.1 Bag type fresh water tank. A collapsible fresh water container of 35 cu ft minimum capacity shall be supplied. This container will be located in the DSRV after sphere and will be used to transport potable water to the MUS.

The container shall be in the form of a cylindrical bellows with an outside diameter that will permit it to move freely within a rigid 38-inch diameter circle when filling or emptying.

An outer fabric reinforcement for dimensional stability, abrasion and puncture resistance; with an integral inner lining of neoprene, vinyl, or similar material is suggested.

Bidder shall state specific materials and molding or fabrication methods being offered for this application.

The container shall be fitted with a removable 1-1/2 inch pipe extending above the bench level, a valve, a male hose connection, and cap, arranged as shown in Drawing 1085809.

The bag type fresh water tank will empty by gravity, aided by the weight of sanitary waste being pumped into the similarly constructed collapsible waste container located on top of it.

3.9.2.2 Flexible under deck fresh water tank. A collapsible fresh water container of approximately 29 cu ft capacity shall be supplied. This container will be located under the access sphere deck and together with the rigid fresh water holding tank, will be used to hold potable water from the DSRV, prior to transfer to the habitat.

This tank shall be molded or fabricated in such a shape that it will hold the required capacity in the available space as illustrated in the accompanying drawings.

The tank material may be the same as that used for the bag type fresh water tank (3.9.2.1). Bidder shall state specific materials and molding or fabrication methods being offered for this application.

The combined capacity of the flexible under deck fresh water tank and the rigid fresh water holding tanks (3.9.2.3) shall be not less than 35 cu ft.

The tank shall be fitted with the following:

a. An internal emptying hose extending to the bottom of the tank, connected to a 1-1/2 inch valve with a male hose connection and cap for filling and emptying.

b. A one-inch removable vent pipe extending approximately 54 in. above the access sphere deck (Dwg. 1085810, Item 13).

3.9.2.3 Fresh water holding tank. Three rigid fresh water holding tanks shall be supplied. These tanks will be located above the deck in the access sphere and together with the flexible underdeck tank, will be used to hold potable water from the DSRV, prior to transfer to the habitat.

These tanks are three of fifteen that must fit around the inside perimeter of the access sphere as illustrated in the accompanying drawings. The inner face of each tanks shall be perpendicular and must not extend into the access sphere by more than 11 inches, measured from the horizontal equator of the sphere. The sides of the central fresh water holding tank shall be parallel to each other to allow insertion of this tank into its

intended location after the placement of the 14 other tanks, thus locking the ring of tanks in place. One side of each of the two adjacent fresh water tanks shall be angled to fit against the sides of the central tank. All other tank sides shall be radial with respect to the access sphere.

The inside radius of the access sphere is approximately 52-7/8 in. The contractor shall determine the actual dimensions of the access sphere after it has been welded and machined, so as to assure proper fit and ease of installation. If this is not practical, the contractor shall provide adequate means of adjustment to permit installation of all tanks in their intended location.

Each fresh water holding tank shall have a capacity of approximately 4 cu ft. The combined capacity of the three fresh water holding tanks and the flexible underdeck tank (3.9.2.2) shall be not less than 35 cu ft.

The tanks shall be fabricated of stainless steel of proper composition and gauge for the intended service. The tanks shall have no internal braces.

Each tank shall be fitted with the following:

a. A 1-1/2 inch bottom connection to the manifold.
b. A one-inch inverted L vent pipe at the top (Dwg. 1085810, Item 12).

The tank immediately counterclockwise from the central tank shall be provided with a bracket suitable for supporting the waste tank vent system filter (Item 7).

The central tank shall be provided with a sight gauge located so that the tank contents may be readily observed before the vent level is reached. The gauge design and construction shall be such that it is not vulnerable to mechanical damage.

The contractor shall supply a 1-1/2 inch manfold (Dwg. 1085810, Item 14) with inlets for each of the three tanks, and a one-inch valve with male hose outlet connection and cap for filling and emptying the water tanks.

3.9.2.4 <u>Fresh water transfer hose.</u> Hose shall be provided of suitable lengths for the following connections:

a. From the bag type fresh water connection in the DSRV after sphere (Dwg. 1085809, Item 21) sequentially to the filling connections of the fresh water tanks in the access sphere (Items 3 and 8).

b. From the rigid fresh water holding tank manifold outlet in the access sphere to the fresh water filling manifold on the top deck of the habitat chamber (Dwg. 1085810, Item 19).

c. From the emptying connection of the flexible under deck fresh water tank in the access sphere to the fresh water filling manifold.

Connection (a) above will not be made at the same time as connections (b) and (c). Two lengths of hose will thus be adequate.

Hose shall be 1-1/2 inch, fabric reinforced plastic or rubber, with female fittings on both ends suitable for the specified connections.

3.9.2.5 Fresh water filling manifold. A manifold consisting of two 1-1/2 inch male hose connection inlets with caps, a valve, and an outlet suitable for connection to the MUS habitat fresh water storage tank line at the upper deck of the habitat chamber shall be supplied.

3.9.3 Sanitary waste equipment. The sanitary waste equipment consists of:

a. Bag type sanitary waste tank with fittings in the DSRV after sphere (Dwg. 1085809, Item 17).

b. Sanitary waste holding tanks and associated fittings in access sphere (Items 2, 4, 6, and 7).

c. Sanitary waste pump (Item 5).

d. Sanitary waste transfer hose (Dwg. 1085809, Item 12; and Dwg. 1085810, Item 26).

e. Sanitary waste discharge connection (Dwg. 1085810, Item 18).

The waste material that this equipment will contain includes solid and liquid human wastes, used wash water, and Benzalkonium and phenolic disinfectants.

3.9.3.1 Bag type sanitary waste tank. A collapsible sanitary waste container of 45 cu ft minimum capacity shall be supplied. This container will be located in the DSRV after cylinder and will be used to transport sanitary waste from the MUS.

The container shall be in the form of a cylindrical bellows with an outside diameter that will permit it to move freely within a rigid 38 inch diameter circle when filling or emptying. The container will be placed on top of the bag type fresh water tank (3.9.2.1), and should be of similar design and construction. The overall height of the bag type was waste tank shall not be so great as to interfere with hose removal when placed in its intended location and filled to its specified minimum capacity.

External support stanchions (Dwg. 1085809, Item 23) shall be supplied to insure stability of the filled bag type tanks.

An outer fabric reinforcement for dimensional stability, abrasion and puncture resistance; with an integral inner lining of neoprene, vinyl, or similar material is suggested. Bidder shall state specific materials and molding or fabrication methods being offered for this application.

The container shall be fitted with a check valve and 2-1/2 in. male threaded inlet hose connection with cap.

A tank separation divider shall be provided for installation between the waste and the water containers to permit visual verification of waste tank integrity (Dwg. 1085809, Item 20). This shall be a non-absorbent, transparent material such as clear vinyl, approximately 1/8 inch thick, and approximately 1 inch larger in diameter than the waste and water containers.

3.9.3.2 Sanitary waste holding tanks. Twelve rigid sanitary waste holding tanks shall be supplied. These tanks will be located above the deck in the access sphere and will be used to hold sanitary waste from the MUS habitat, prior to transfer to the DSRV.

These tanks are twelve of fifteen that must fit around the inside perimeter of the access sphere as illustrated in the drawings and described in 3.9.2.3. The dimensional constraints and installation fit requirements specified for the water tanks in 3.9.2.3 shall be met for the sanitary waste holding tanks.

The inner face of each tank shall be perpendicular, and the adjoining two sides shall be radial with respect to the access sphere.

Each sanitary waste holding tank shall have a capacity of approximately 4 cu ft. The combined capacity of the twelve waste tanks shall be not less than 45 cu ft. The waste material level must not rise to the vent connections at this capacity. The tanks shall be fabricated of stainless steel of proper composition and gauge for the intended service. The tanks shall have no internal braces.

Each tank shall be fitted with the following:

a. A three-inch bottom connection to the draining and filling header, located so that all tanks can be drained completely.

b. A one-inch top connection to the vent header.

A one-inch vent header (Dwg. 1085809, Item 6) shall be provided, connecting all tanks to a filter.

An activated charcoal filter (Item 7) shall be provided, secured to the bracket on the

adjacent water tank, and of adequate capacity and design to effectively minimize odors from the waste tank system over a normal 30-day operational cycle.

A three-inch draining and filling header shall be provided (Item 4). This header shall connect all waste tanks to the filling connection (Dwg. 1085810, Item 22), and to the sanitary waste pump (Item 5).

The filling connection shall consist of a 2-1/2 inch plug valve or gate valve, with threaded male hose connection and cap.

3.9.3.3 Sanitary waste pump. A pump shall be provided to pump the sanitary waste from the holding tanks in the access sphere to the bag type tank in the DSRV after sphere. The pump shall be rated at approximately 20 gpm, and shall be complete with motor and control, with integral foundation. The pump shall have a three-inch intake with gate valve or plug valve between the intake and the draining and filling header (Dwg. 1085809, Item 4), and a 2-1/2 inch discharge with threaded male hose connection and cap.

3.9.3.4 Sanitary waste transfer hose. Hose shall be provided of suitable length for the following connections:

a. From the sanitary waste discharge connection on the MUS habitat top deck (Dwg. 1085810, Item 18) to the sanitary waste tank filling connection in the access sphere (Dwg. 1085810, Item 22).

b. From the sanitary waste pump discharge (Item 5) to the bag type sanitary waste tank inlet connection in the DSRV after sphere (Dwg. 1085809, Item 17). (Note that this connection will rise when the bag type tank is filled.)

Connection (a) will not be made at the same time as connection (b). One length of hose will thus be adequate.

Hose shall be 2-1/2 in. inside diameter, rubber or plastic lined, and fabric reinforced. Hose shall be reasonably flexible to facilitate storage. Each end of the hose shall be equipped with a brass valve and threaded female connection. Fittings shall be constructed to facilitate cleaning with brush and disinfectant.

3.9.3.5 Sanitary waste discharge connection. A discharge connection consisting of an elbow with 2-1/2 inch threaded male hose connection and cap, suitable for connection to the MUS habitat waste line at the upper deck of the habitat chamber, shall be supplied.

3.9.4 Supply handling equipment. The supply handling equipment consists of:

a. Handling hoist (Dwg. 1085810, Item 11).

b. Handling chute (Dwg. 1085810, Item 16).

c. Three hatch collars (Dwg. 1085809, Items 9 and 13; Dwg. 1085810, Item 9).

d. Deck grating (Dwg. 1085810, Item 21).

e. Loading platform (Dwg. 1085809, Item 19).

3.9.4.1 Handling hoist. A hoist shall be supplied to assist in raising and lowering supplies from the access sphere through the open hatch into the habitat cylinder. This shall consist of one single block and tackle pulley and a suitable bracket in the access sphere. The sheave shall have a 4-inch outside diameter with a 1/2 inch deep groove seat. The pulley and hoisting rope shall have a 300-lb test capacity. The rope shall have a hook attached for lifting the supply containers.

3.9.4.2 Handling chute. A handling chute shall be supplied to guide the supply packages as they are transferred from the access sphere to the top deck of the MUS habitat. This lightweight stiffened aluminum channel shaped chute shall be approximately 10 ft in length to traverse the span from the hatch to the deck level and shall be separable into two approximately equal length sections for storing in the access sphere when not in use. The chute must be capable of accommodating 15 in. wide packages between its support guides. The overall width of the chute shall not exceed 16 inches.

3.9.4.3 Hatch collars. Protective collars shall be supplied to prevent damage to the machined sealing surfaces of all the hatches in the DSRV and MUS when supplies are passed through.

Two 1/4 inch thick rubber grommet-like collars shall be supplied: one each for the bottom hatch in the DSRV, and the top entrance hatch to the access sphere (Dwg. 1085809, Items 9 and 13). These collars will have an I.D. of 25 inches with a 3 inch lip extending both top and bottom to cover and protect the upper and lower surfaces of the hatch opening. The rubber collars must be flexible enough for rapid removal and storage when the hatch is to be closed.

A 1/8 inch thick semi-rigid fiberglas collar shall be supplied to protect the top hatch of the habitat (Dwg. 1085810, Item 9). This collar has a cylindrical seat approximately 25 inches in diameter by 4 inches long with a 3 inch wide lip. The collar will normally be installed from above, and will be stowed in the access sphere.

3.9.4.4 Deck grating. Aluminum deck grating shall be supplied to provide a platform for the crew to walk on and a flat surface upon which to stack supplies inside the

access sphere. The grating shall be capable of supporting a uniform load of 250 lbs. per square foot. The maximum clear opening between the grating bearing bars should not exceed 1.0 inch. The maximum width of each separate grating strip shall be 6 inches.

3.9.4.5 DSRV loading platform. A revolving loading platform shall be supplied for stacking supplies in the DSRV after sphere. The loading platform shall have O. D. of 72 inches and an I. D. of 38 inches, basically matching the existing rescue seat in the after sphere. The platform shall be set upon a series of ball bearings and races to allow revolving the platform when fully loaded. The platform shall be capable of supporting and revolving when loaded with 1000 lbs of stores. The platform must revolve smoothly with the load concentrated on one side or in any other arrangement.

3.9.5 Utility equipment. The utility equipment is comprised of incandescent lights (Dwg. 1085810, Item 10) to illuminate the access sphere interior and a blower (Item 17) to ventilate the access sphere when it is open to the habitat.

3.9.5.1 Interior lights. Two watertight 120-volt light fixtures with 100-watt lamps shall be provided for interior illumination of the access sphere. Each light shall be fitted with a stiff wire mesh guard covering the outer glass globe to protect against possible breakage. A suitable on-off switch shall be provided.

3.9.5.2 Centrifugal blower. A portable centrifugal blower shall be supplied to ventilate and cool the access sphere. The fan shall include a 1/4 hp direct drive electric motor, operating on 120-volts ac. The fan ring shall not exceed 12 inches in diameter. The blower must be capable of delivering 750 cubic feet per minute. A 10 ft long, 3 in. diameter flexible plastic hose shall be supplied to carry the blower discharge from the top level of the habitat to the access sphere through the open hatch. Power for the blower will be supplied from the habitat electrical distribution system.

3.9.6 Safety equipment. A system shall be provided to detect the presence of sea water in the access chamber and to alert the Station crew to the situation. The system shall include sea water sensors installed in the lower portion of the access chamber which transmit signals, via hard wire to the environmental monitoring console located in the habitat. An audible alarm shall alert the crew, and appropriate indications on the console shall identify the source of trouble.

3.9.7 Power distribution equipment. Electrical power shall be supplied to the access sphere to operate the sanitary waste pump and the incandescent lights located in the sphere. Power to the access sphere may be supplied from the reactor cylinder, through the reactor cylinder hatch.

The total access sphere power requirement is approximately 1 kw at 120-volts single phase, 60 cycle.

3.9.7.1 Penetrator. A pressure hull penetrator shall be supplied to allow transmission of electrical power into the access sphere with the hatches closed. The penetrator must be capable of withstanding 150% of the pressure for the maximum design operating depth for MUS.[1] The penetrator receptacle shall contain the male contacts. The pressure resistant bulkhead in which the receptacle pins are mounted shall be fused glass sealed. Penetrator receptacles, either mated to plug or unmated shall be capable of withstanding 150% of the pressure for the maximum design operating depth.

3.9.7.2 Cables. Standard Navy cables shall be employed. Cable runs should be located so as to avoid physical interference with equipment within the access sphere. The cable shall have a minimum voltage rating of 300 volts.

3.10 Chemical and physical properties. There are no applicable requirements.

3.11 Radio interference suppression. There are no applicable requirements.

3.12 Dimensions. All components and equipment shall be properly sized and contoured for installation in their intended locations as shown on the drawings. Contractor shall verify all critical dimensions before final design and manufacture, although the accompanying drawings may be scaled for general information.

All components and equipment must pass through a 25-in. diameter hatch prior to installation.

3.13 Weight. All components and equipment shall be of minimum weight, consistent with good design practice. Bidder shall state maximum total weight of all equipment offered for installation or use in each separate location (DSRV after sphere, MUS access sphere, and MUS habitat upper deck).

3.14 Color. There are no applicable requirements.

3.15 Finish. So far as is consistent with good design practice, all equipment and components shall be supplied with their natural surfaces unfinished, to facilitate inspection while in service. Any finishing materials used shall comply with appropriate U. S. Navy specifications for submarine service.

3.16 Nameplates and product mountings. Nameplates and product markings shall be furnished where appropriate. Markings shall be designed to remain legible throughout the service life of the equipment on which they are mounted.

3.17 Government-furnished property.

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[1] 2700 psi at 6000 ft

3.18 Government-loaned property.

3.19 Workmanship. All equipment and components shall be manufactured from new materials and finished in a thoroughly workmanlike manner. Units shall be thoroughly cleaned of all foreign material, internally and externally. All surfaces shall be clean and free from smudges, scratches, or other marks which detract from a new appearance.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Quality conformance inspection. Inspection shall be made on every item offered for delivery and shall comprise such examination and testing as are necessary to prove the workmanship and all other requirements of this specification. All equipment shall be examined for:

a. Workmanship, assembly and fit, mechanical safety, and marking.

b. Materials, parts, and finish.

c. Weights and dimensions of all units and parts shall be determined.

d. Pressure integrity.

e. Operation.

4.3 Test methods. Tests shall be performed in accordance with the contractors normal procedures to prove that all molded or fabricated containers; hose; and assembled valves, fittings, or other furnishings will remain free of leaks under the intended service conditions. As a minimum, hydrostatic tests shall be performed at 150 percent of service operating pressures. Contractor shall furnish all accessories necessary for the performance of tests.

Tests shall be performed to verify proper operation of the motor and pump assembly, and may be in accordance with the manufacturer's standard practice.

4.4 Test records. Certified records of all tests and inspections, in the supplier's standard format, shall be furnished to the Government. Records shall include performance data for motor and pump assembly.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Cleaning, drying, preservation, and packaging shall be in accordance with the manufacturer's commercial practice.

5.2 Packing. Equipment packaged as specified in 5.1 shall be packed in a manner to insure carrier acceptance and safe delivery at destination by ocean vessel shipment. Containers shall be in accordance with Uniform Freight Classification Rules or regulations of other carriers applicable to the mode of transportation.

5.3 Marking. In addition to any special marking required by the contract or order, unit packages, intermediate packages, and shipping containers shall be marked in accordance with the requirements of MIL-STD-129.

6. NOTES

6.1 Intended use. The equipment covered by this specification is intended for Naval service in a deeply placed manned underwater habitat where it is expected to withstand monthly periodic use over long periods without benefit of overhaul. This equipment is vital to the transfer of essential supplies to the habitat, and the necessary removal of waste materials. Failure of function could result in extreme discomfort and deprivation of personnel, an aborted mission, and great expense to the Government.

6.2 Ordering data. Procurement documents should specify the following:

a. Quantity.

b. Reference to this specification.

c. Acceptance requirements.

d. Documentation requirements, including drawing submittal and approval, if required.

e. Time and place of delivery to the Government.

f. Marking.

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9.0 RECOMMENDATIONS

During preparation of this report several topics have materialized which require work beyond the scope of the present contract for full development. Included are those below which are particularly applicable to Manned Underwater Stations. It is recommended that these topics be pursued in subsequent studies.

9.1 SEA ELEVATOR CONTROL

As discussed in 5.2, sea elevators or diving bells can be utilized as alternatives to free swimming vehicles for Station resupply. The major problems associated with such usage are surface effects and guidance to and indexing with the mating platforms at depths below diver capability.

The problem of providing a stable platform to decouple the elevator from surface wave forces is discussed briefly in Section 5.2, however an optimum system has not been developed and the problem merits additional attention.

Two solutions to the guidance problem have been suggested. A messenger cable attached to the Station and means to center the bell as it approaches the mating pad are depicted in Section 5.3. The addition of small thrusters to the bell is an alternative which eliminates the need for a messenger cable and indexing devices. Both of these concepts must be further investigated to determine forces involved and to develop feasible control systems.

9.2 MUS TECHNICAL DEVELOPMENT PLAN (TDP)

The Manned Underwater Station is responsive to the Deep Ocean Technology (DOT) Project One Atmosphere Operations Center requirements for underwater construction. The DOT TDP, written in response to ADO-46-36X, recommends that the

Principle Development Activities provide a TDP for each major element of the DOT Project. The Naval Facilities Engineering Command has been designated as the Principle Development Activity for the DOT Project Site Preparation and Construction Subsystem. The next step prior to initiating development is submission of a TDP for the One Atmosphere Operations Center/Manned Underwater Station as part of the DOT Project.

The IES study provides valuable data for such document. TDP Section 4, Narrative of Requirements and Brief Development Plan; Section 8, Subsystem Requirements; Section 9, Associated Subsystems and Section 11, Operability and Supportability Plan would draw heavily on the IES results and provide additional information.

Section 4, Narrative of Requirements and Brief Development Plan requires further effort. The logical development of the requirements for the Manned Underwater Station from the role it is to play in the DOT Project is of particular importance here.

Section 7, Block Diagrams and Section 8, Subsystem Requirements will utilize the results of several studies, however, a broad based set of system requirements with only the essential constraints should be included.

Sections 10 thru 14 cover Reliability and Maintainability Plan, Operability and Supportability Plan, Test and Evaluation Plan, Personnel and Training Plan, and Production, Delivery and Installation Plan. These sections are often treated in broad general terms quoting the directives, manuals and specifications without truly addressing the particular system at hand. The unique character of the Manned Underwater Station offers the opportunity to develop these sections in a framework relating to the specific needs of the program. The effect of these plans upon the system is highly significant in terms of cost, schedule and ultimate results, and they must be properly related to the problems at hand. Such problems as underwater installation and maintenance require a sophisticated and realistic approach to effectively utilize past experience as it applies to this unique environment.

A TDP, properly prepared, will provide a substantive plan for implementation of Manned Underwater Stations. The TDP, and support data generated during its preparation, will ease incorporation of MUS in the DOT Project Master Plan and will form a basis for justification of required funding.

9.3 AERIAL RESUPPLY CONCEPTS

As discussed in Section 5.3, aerial resupply has several advantages when compared to vehicle or conventional bell type resupply, especially for small loads. If the Station site is some distance from shore based support, considerable time may be saved. No complex surface support ship is required and the problems of surface forces associated with sea elevators are mitigated.

Several areas require additional work before such a system can be implemented. Modifications to the access chamber and the addition of a winch chamber are required. Chamber dewatering systems must be provided. (Access chamber dewatering would also allow deployment of acoustic or other sensors from the Station to expand mission capabilities.) Supply sphere, supply cylinders, cargo package and subsystems must be designed. Study of these areas will yield valuable data for Manned Underwater Station systems.

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13. ABSTRACT

The design provides means to resupply a Manned Underwater Station on the ocean bottom. Environmental and logistics constraints are defined and alternatives to the baseline system are suggested. An outline specification for equipment is included. (U)

The baseline system utilizes a Deep Submergence Rescue Vehicle (DSRV) suitably modified for Station resupply. The operation is thus performed only once in 30 days for a 5 man Station. If, when the Station is actually deployed, a DSRV is not available, other methods utilizing diving bell type structures may be employed. (U)

Of the three candidate site areas examined, San Clemente, Hawaii and Kauai Islands, Hawaii is most advantageous based on environmental and bathymetric considerations. (U)

Under the constraints of the study a single 9-foot diameter sphere has been chosen for an access chamber. Other configurations have advantages, especially that of utilizing the upper portion of the reactor cylinder for main access. (U)

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